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Published every Friday by
The Machinery Publishing Co., Ltd.
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MACHINERY

A JOURNAL OF METAL-WORKING PRACTICE AND MACHINE TOOLS

Vol. 92, No. 2371 April 25, 1958

COPIES PRINTED.....11,500 per week

CERTIFIED DISTRIBUTION.....11,376 per week

CERTIFIED PAID DISTRIBUTION.....10,566 per week

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Abstracts of Principal Articles

Fairey 3-dimensional Contour Milling Machine with Ferranti Magnetic Tape Control System .....P. 932

An important result of investigations carried out by the Fairey Aviation Co., Ltd., on the high-speed milling of light alloy parts required for aircraft of integral construction, has been the design and production of a 3-dimensional contour milling machine. This machine has been developed and built with the support of the Ministry of Supply, and incorporates the Ferranti system of magnetic-tape control, and a number of interesting design features. The machine is of the travelling column type and has a vertical work-table measuring 28 by 8 ft. All the traverse motions are tape controlled, with facilities for manual control by push buttons. It was appreciated at the outset, that for a completely successful application of tape control, exceedingly smooth and sensitive traverse movements would be required, and, following extensive tests, a system of hydrostatic lubrication has been developed which gives outstanding results and is the subject of British and U.S. patents. The servo-drive system, which incorporates hydraulic motors and ball-nut and screw assemblies, has also been the subject of careful study. Information that has now been made available for publication indicates that this machine represents a development of first importance in the machine tool field. (MACHINERY, 92—25/4/58.)

Producing the Vauxhall Victor.....P. 944

In this second article of a series, some of the more interesting operations on gearbox components for the recently introduced Vauxhall Victor car are described. The mainshaft of the gearbox is supported at each end in bearings carried in front and rear covers, and the machining of these components is first considered. Special fine-boring machines are employed for finishing the bearing housing bores and mounting faces, also for plunge-cutting circlip grooves. The new gearbox is arranged for synchromesh engagement of first gear, and operations on a clutch hub which forms part of the mechanism are next described, including automatic loading of blanks in a chucking automatic and on a battery of gear-hobbing machines. Three slots are then broached in the sides of the hubs, after which the teeth are hardened in three positions on a special automatic induction-heating machine. On the gearbox mainshaft, four sets of 33 oil grooves are required in journal portions on which gears turn in the finished assembly, and these are produced very rapidly on a spline-rolling machine. Finally, a duplex machine for induction-hardening certain surfaces on striking levers and forks is discussed. The machine has two separate fixtures and is arranged for automatic unloading of the parts. (MACHINERY, 92—25/4/58.)

The Dimensioning and Quality Control of Involute Splines .....P. 963

In recent years, multi-tooth involute splines have been adopted increasingly by the engineering industry, and their introduction has resulted in a number of problems connected with the dimensioning and gauging of the splined members. This article describes the method of dimensional control which was proposed by the Vinco Corporation, Detroit, Michigan, U.S.A., and subsequently included in the American Standard for involute splines in 1950. The various factors which can affect the fit obtained by a pair of splined members are discussed, and the derivation and application of " effective " and " actual " dimensions for tooth-thickness and space-width are explained. There are three control systems, to suit various applications, and the two basic types of splined connection, flank-fitting and major-diameter fitting, are described, as are the various types of plug and ring gauges required for inspecting the parts. Examples are given of typical fully-dimensional workpieces, tooling and inspection charts, and inspection flow charts. (MACHINERY, 92—25/4/58.)

Pressure Die Casting of Necchi Sewing Machine Components .....P. 973

In this second article on the Necchi die casting foundry are described the machines and dies employed for two of the more interesting sewing machine arm components now being produced. The first die discussed is employed on a 750-ton Triulzi cold-chamber machine for the production of a combined arm and bed casting for the new Mirella domestic sewing machine. Two horizontally-moving cores in this die are operated by cam tracks in pairs of bars which project at each side of the die, and a third core beneath the die is operated by cam pins. These cores produce internal surfaces of extreme intricacy in the casting. Cast in aluminium alloy, this component weighs 4.5 lb. in the trimmed condition. Another die, for casting the Supernova sewing machine arm, is operated on a 400-ton Bühler machine and has three hydraulically- and two cam pin-operated cores. In addition there are two loose cores which are ejected from the die with the casting, a spare set being employed to avoid production delays. For removing flash from cored holes in this casting, two special machines built by the company are employed. These machines operate on automatic cycles and eliminate much laborious hand work. (MACHINERY, 92—25/4/58.)

IN FORTHCOMING ISSUES

Construction and application of C.M.B.G. rotary transfer presses—Hand tool production in a Swedish factory.

Precision Forging

There is a growing tendency, in many fields of production, to make greater use of plastic deformation processes, whereby metal is caused to flow, under pressure, to conform to the required finished shape, or to an approximation of that shape such that the amount of machining subsequently necessary is comparatively small. Much has already been learned concerning the conditions conducive to metal flow and the design of tools to withstand the severe conditions that may be involved. With the further development of tool materials and of presses suitable for these operations, it is likely that the scale of application will continue to increase, and that larger and more intricate forms will be produced.

During recent years, the rapid advances that have been made in connection with cold extrusion or "cold flow pressing" as the process is sometimes termed, have, perhaps, tended to divert attention from the possibilities of precision hot forging. With normal die forging, which is such an invaluable method of preparing a diversity of workpieces for subsequent machining, it is customary to provide fairly substantial allowances, so that reasonable die wear can be tolerated, and scale formation on the material surface is not particularly detrimental. On the other hand, it has been established that, provided certain precautions are observed and the tools are kept in very good condition, some shapes can be hot forged to close limits of accuracy and with high surface finish, so that little or no finish machining is needed. In particular, this procedure has been employed with success by some manufacturers of gas turbine blades, who have thus overcome the problems associated with the production of intricate aerofoil forms by machining.

At this point is should be emphasized that the advantages of plastic deformation are not limited to the avoidance of machine shop difficulties. It has long been established that the flow of material not only results in improved properties but often provides a more favourable grain formation, and, within reason, the more drastic the deformation the stronger is the finished part. In this connection, well known examples are afforded by rolled threads as compared with cut threads, and forged crankshafts as compared with those machined from solid bar. It follows, therefore, that, in general, the smaller the amount of machining necessary after cold extrusion or precision forging, the better will be the finished product.

Even when the best tool materials are employed, the life of precision hot forging dies is necessarily fairly short, and the closer the work limits specified the fewer is the number of parts produced before reconditioning is required. Consequently, if it was essential to rely on conventional methods of die sinking and reconditioning, tool costs would very seriously restrict the potential applications of the process. Fortunately, however, the introduction of new die making methods, such as spark- and ultrasonic-machining, have enabled some types of tools to be produced much more economically. Once a cavity of the required form and accuracy has been obtained, moreover, provision can often be made for expeditious reconditioning.

With the facilities now available, it appears that the possibilities of precision hot forging might usefully be re-examined, and some interesting observations on this subject were made by Mr. John F. Murphy, during the course of a paper presented at the recent Production Meeting and Forum of the Society of Automotive Engineers. Attention was drawn to the work that has been done in Germany in connection with the finish forging of gears on friction screw presses, and it was stated that, in spite of the rather short die life, items ranging from pinions of 1 in. diameter to hypoid ring gears up to about 8 in. diameter were being produced commercially.

According to the author, the tolerances obtainable are satisfactory for most applications without any further operations on the gear teeth, and it was indicated that very little distortion of the gears occurs if they are subsequently carburized and heat treated.

It was emphasized that for plain gears the forging method is not competitive with gang hobbing and other high production processes. On the other hand, it has proved effective for certain straight and spiral bevel gears, and in some instances it enables one-piece components, incorporating gears, to be substituted for built-up assemblies. As an example, a motor cycle part was mentioned, which comprises an interrupted spur starter gear, a bevel gear, a cam, and a shaft. These parts are now integral, whereas they were formerly made separately and assembled.

(*Continued on page* 899)

Fairey 3-dimensional Contour Milling Machine with Ferranti Magnetic Tape Control System

Reference has previously been made in MACHINERY* to the facilities which the Fairey Aviation Co., Ltd., have built up for the design and construction of special-purpose machine tools and equipment required in the production of modern aircraft, and in this field they have made some noteworthy advances. Investigation of the problems involved in integral construction, with particular reference to the high-speed milling of light alloys, has been actively pursued during the past few years, and a major result of this work has been the design and construction, with the support of the Ministry of Supply, of a large 3-dimensional contour milling machine, incorporating the Ferranti system of magnetic tape control. This machine is now undergoing a series of acceptance tests at the company's Stockport works, and information on some of the outstanding design features can now be given.

As may be seen in Fig. 1, the machine is of the travelling column type and it has a vertical work table which measures 28 by 8 ft. The column has a traverse of 25 ft. along the bed, the spindle saddle has a vertical traverse of 7 ft. on the column, and the spindle head has a transverse horizontal movement of 12 in. in the saddle. All these motions are normally tape controlled, but there are also facilities for manual control by push buttons.

In designing this machine, it was appreciated, at the outset, that for a completely successful application of the tape control system, traverse movements of much greater smoothness and sensitivity than are obtained on conventional heavy machine tools would be required. To this end, a detailed study was made, and various experiments were carried out, particularly on slideway lubrication, before the basic design was established. As a result of this work, a system of hydrostatic lubrication has been developed which gives outstanding results, and is the subject of British and U.S. patents.

The same consideration was given to the traverse drive systems, and it was finally decided that the

* Abstract of a paper on "Time Saving in the Aircraft Industry" given by Mr. H. G. Gregory, M.I.Prod.E., and Mr. A. Vines, A.M.I.Prod.E., of the Fairey Aviation Co., Ltd., at the Fourth Aircraft Production Conference organized by the Institution of Production Engineers published in MACHINERY 88/151-20/1/56.

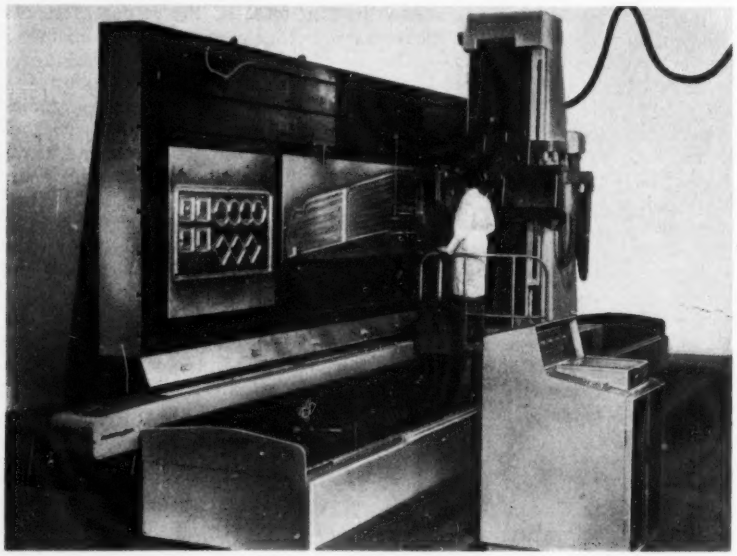


Fig. 1. The Tape-controlled 3-dimensional Milling Machine Developed and Built by the Fairey Aviation Co., Ltd., in conjunction with Ferranti, Ltd.

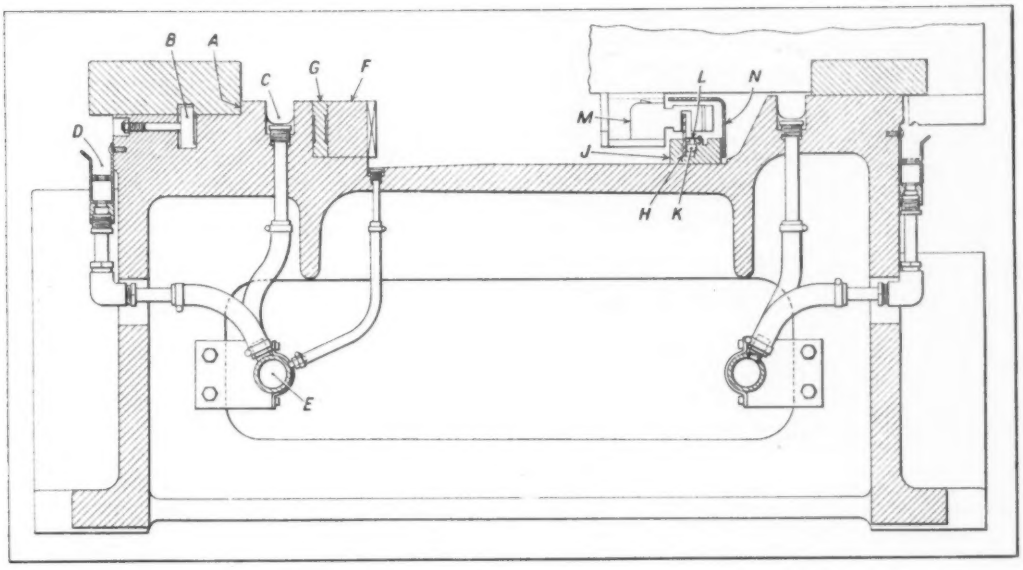


Fig. 2. Arrangement of the Bedways on the Fairey Tape-controlled Milling Machine. A Very Sensitive Movement for the Column is Ensured by a Patented System of Hydrostatic Lubrication

power should be provided by hydraulic motors coupled to double-train reduction gearboxes, arranged with axial pre-loading for the elimination of backlash. For the column and spindle saddle movements, the final drive is taken through double pinions meshing with fixed racks, while the 12 in. of cross movement for the spindle head is obtained by a screw and nut of the ball-circulating type.

SLIDEWAY DESIGN

A sectional view of the bed, showing the arrangement of the slideways, which are of rectangular form, is given in Fig. 2. The ways comprise 5-ft. long, hardened and ground Nitralloy steel strips, which are 8 in. wide by 2⅝ in. thick at the left-hand side, and 6 in. wide by 1⅝ in. thick at the right. They are ground to a tolerance of 0·0002 in. for thickness and parallelism, and are secured to the planed and carefully-scraped bed surfaces by socket-head screws and dowels. The machine column is carried on a separate, 5-ft. 6-in. long base casting, and lateral location is taken from the left-hand way only, which thus forms a long narrow guide. Accurate alignment of the left-hand Nitralloy way members is provided by an abutment face *A*, on the bed, against which the ways are held by clamp plates as at *B*. Each clamp plate is provided with a heel at the lower end, which bears against the vertical face of the bed groove, and clamping is effected by means of a thrust peg, screw and lock nut. Spheroidal graphite cast iron, which has good bearing properties, has been chosen for the column base, and the casting was supplied by the Hollinwood foundry of Ferranti, Ltd.,

The holes for the socket-head screws and dowels in the top surfaces of the ways are finished flush by the application of metal-filled plastics, to obviate any pockets, other than those expressly provided for lubrication purposes. As a precaution against the screws and dowels becoming locked in position by the plastics, the heads were first coated with beeswax, to ensure easy removal, if necessary. The slideways of the column and spindle head are of generally similar design, and the spindle saddle is also of Ferranti spheroidal graphite cast iron.

LUBRICATING SYSTEM

The hydrostatic lubrication system that is incorporated for the ways of the bed, the column, and the spindle saddle, provides for the supply of oil, at a pre-set pressure, through a metering system to suitably-disposed pockets in the bearing surfaces of the sliding members in contact with the top, side, and keep-plate faces of the Nitralloy ways.

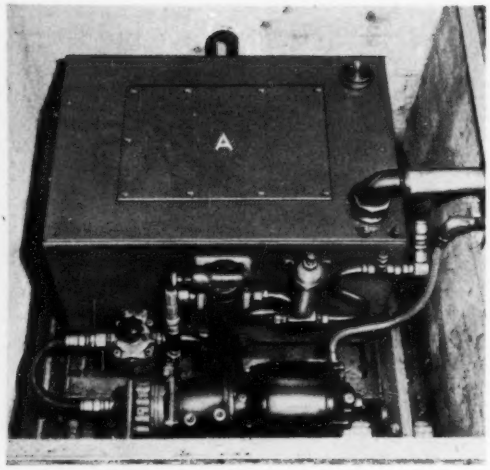


Fig. 3. A View of the Lubrication Pump Unit for the Slideways. It is Housed in a Pit at the Left-hand End of the Bed

A very fine clearance is purposely provided between each bearing surface of the ways and the corresponding surface of the sliding member, and the pre-set pressure drop provided by the system results in an oil film of known thickness being substantially maintained throughout all conditions of loading for which the machine is designed. As previously stated, the system is at present the subject of patent applications, and, while full details are not yet available for publication, the results that have been obtained indicate that the moving members do, in fact, float on oil. Thus, conditions are provided which enable full advantage to be taken of the accuracy and speed of response of the tape-control system. Details will be given later of some of the interesting tests that have been carried out, with experimental set-ups, and also on the machine itself during construction.

The oil supply for lubrication purposes is provided by a pump unit, housed separately from the machine in a floor pit at the left-hand end of the bed, so that any slight vibration from this source does not affect the operation of the machine servo system. A view of this unit is given in Fig. 3.

Oil is delivered at a pressure of 400 lb. per sq. in., through a filter, a reducing valve, and a small smoothing accumulator, to a pipe line which extends through the bed to a distribution manifold in the centre, at the front. From this manifold, the oil is delivered by way of a flexible rubber hose to another manifold located on the column saddle, and thence by pipe to a control panel on the side of the column, which is seen in Fig. 4. Here, the oil passes through a Fairey Microfilter capable of removing particles as small as to 5 microns, and it is then delivered by a system of pipes to the slideway pockets.

Oil flows from the ends of the column saddle at virtually zero pressure, and is collected in channels as at *C* and *D*, Fig. 2, below the ways. These channels are connected by a series of ¾-in. bore rubber hoses to the return pipes *F*, the latter merging into a single pipe which delivers it to the supply tank *A*, Fig. 3, of the pump unit. Suitably-disposed channels are also provided for collecting and returning the oil from the ways of the column and spindle saddle.

SOME TEST RESULTS ON SLIDEWAYS

The 32-ft. long bed of the machine is made up of two sections of 14 ft. and one of 4 ft., which are provided with end flanges and are bolted and dowelled together. When the machine was being built, a 14-ft. length of bed was first completed, and tests were then carried out on the hydrostatic lubrication system which had been developed previously on an experimental basis.

For test purposes, the column saddle member only, which weighs one ton, was used, and addi-

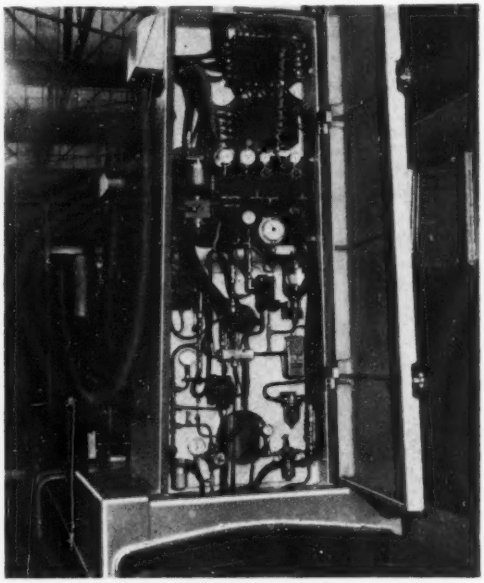


Fig. 4. View of the Control Equipment Panel on the Machine Column

tional loads up to 8 tons were applied to represent the total weight of the column and spindle head assembly. As previously indicated, the results obtained were remarkable. It was found, for example, that the loaded saddle could be moved along the bed by a weight of only about 2 lb., attached to a length of ordinary sewing thread passing over a ball bearing pulley. As another indication of the efficiency of the system, it may be noted that it was found possible to move the saddle merely by pressure applied with a matchstick held endwise between the fingers.

A force of 40 lb. was required to move the saddle smoothly at a speed of 200 in. per min., which is approximately the rapid traverse rate of the machine, and reliable readings for speed could be obtained for traversing forces down to 2 lb. (at a corresponding movement rate of 10 in. per min.), the resulting graph being virtually a straight line. Substantial loads were also applied on a cantilever support to simulate conditions when cutting is in progress. In addition to the bellows covers seen in Fig. 1, the working surfaces are protected by scraper units that are of conventional design, at each end of the saddle. When these scrapers were fitted, an additional moving force of 20 lb. was required.

At this stage, the opportunity was taken to obtain reliable figures of the feeding force required during cutting operations, and, for this purpose, a spindle head was mounted on the saddle, and weights were applied to a cable passing over a pulley at the end of the bed.

Experimental work on slideway lubrication is being continued, and reference may be made to a set-up designed to determine the effects of varying loads with a hydrostatic lubrication system.

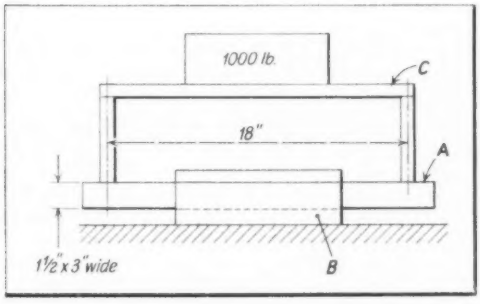


Fig. 5. Diagram Showing the Test Rig for Investigating the Effects of Varying Loads on Slide Member Under Conditions of Hydrostatic Lubrication

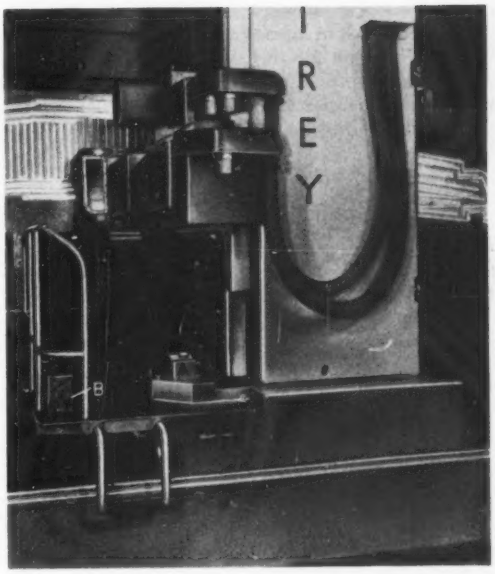


Fig. 6. Close-up View of the Column and Spindle Head of the Fairey Machine

The test rig employed is shown diagrammatically in Fig. 5. A 3-in. wide by 1½-in. thick, hardened and ground slide bar *A*, of Nitralloy steel, is arranged to move in a 10-in. long, enclosed guideway *B*, of ordinary soft mild steel. The bearing surfaces of this guideway are ground, and provide a very fine clearance, on all sides, for the slide bar. Lubricating oil is delivered under pressure to the surfaces of the guideway, and loads are applied by placing weights on a bridge member *C*, of fabricated steel, which has a span of 18 in.

With an applied load of 1,000 lb., it was not possible to move the slide bar by hand with the lubricating pump switched off, although the surfaces were flooded with oil. When the pump was switched on, however, the slide could easily be moved by light finger pressure. The test rig was set up on the machined top surface of a fabricated steel stand, which proved to be out of level by a very small amount. This inclination, although slight, caused the loaded slide bar to move to one end of the guideway under gravity. The finger pressure required to move the slide bar was substantially the same when the load was applied at one end of the bridge, also when it was removed altogether. This test, and others, have shown that the lubrication system imparts a very high degree

of "stiffness" to the slide and guideway assembly, and it also has the advantage of averaging out any waviness errors in the ways. An air-flotation system, while providing for easy movement, would not give the same rigidity because of the compressibility of the air film.

SERVO DRIVE SYSTEMS

The pinion and rack drives and servo gearboxes for traversing the column along the bed, and the spindle saddle vertically on the column, are of Fairey design, and, as already mentioned, they incorporate double gear trains for the elimination of backlash. Traverse speeds up to 120 in. per min. are available for continuous operation, and up to 180 in. per min. intermittently, for setting purposes. The spur tooth bed rack for the column traverse is seen at *F* in Fig. 2. It is fastened vertically, by socket-head screws and dowels, and a backing plate *G* is fitted to facilitate setting the rack for depth of mesh with the pinions. This rack is made up of 18-in. long hardened and ground steel sections, which were produced at the company's Hayes, Middlesex, works. The face width is 3 in., and the straight teeth, of 4 D.P., were form ground, using a full-form wheel, on a Jones & Shipman surface grinder equipped with a special fixture, the work being indexed from one tooth to the next by inserting accurate spacing blocks. Lubrication is effected by drip feed from the slideway oil pressure system, and the oil is returned by pipe to the supply tank at the end of the bed.

The gearbox and hydraulic motor for traversing the column along the bed, also the associated control valve, are housed as a unit in the top face of the column saddle, as indicated at *A* in Fig. 6, and the arrangement of the vertical drive is generally similar. As may be seen in the drawing, Fig. 7, which relates to the vertical drive, there are two gearbox sections, and the upper, input section, is spigot-located and secured by bolts to the lower section. Fig. 8 is a sectional view of the two gearboxes separated, with the gear centres of the lower box expanded to enable the arrangement to be seen more clearly.

In this vertical drive system, a Vickers-Detroit, axial-piston-type hydraulic motor, of 4·4 h.p. continuous rating at a maximum speed of 5,500 r.p.m., is employed. For intermittent operation, the speed can be increased to 8,250 r.p.m., when a maximum torque of 14 lb.-in., is provided. A hydraulic motor of 7·3 h.p. continuous rating, at a maximum speed of 3,400 r.p.m., is employed

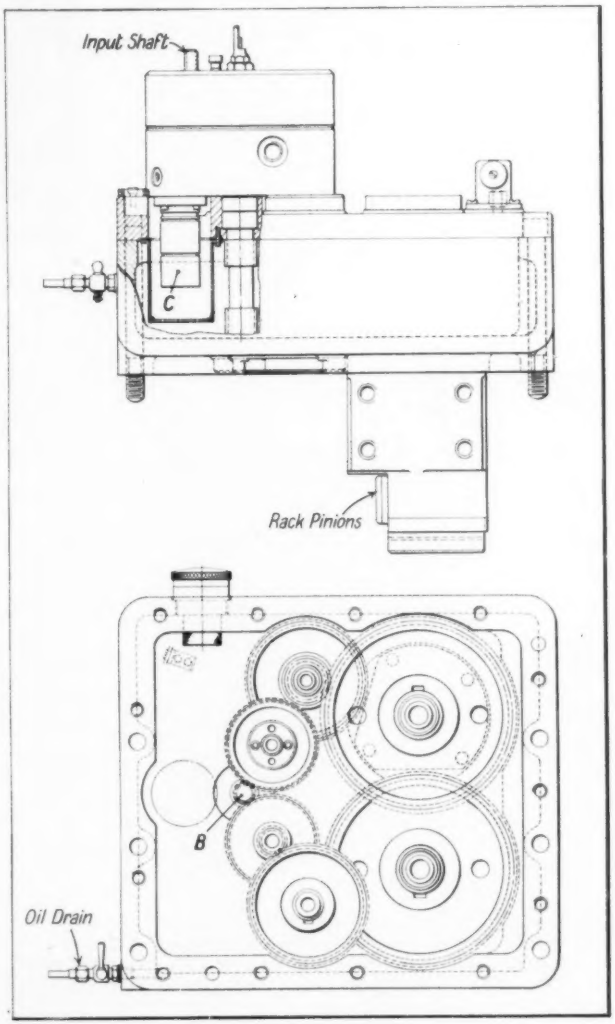


Fig. 7. General Arrangement of the Two Sections of the Fairey Servo Gearbox

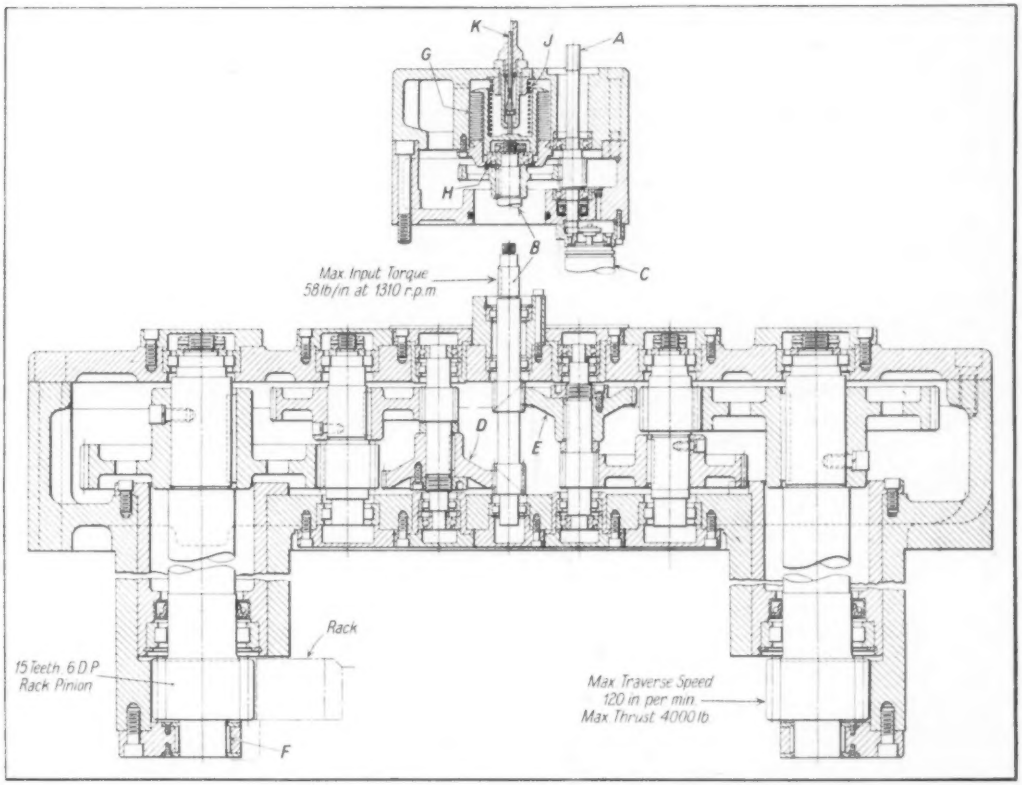


Fig. 8. Sectional View of the Two Gearbox Units. The Lower, Main Gearbox has been Expanded to Show the Arrangement of the Gears

to power the column traversing drive system.

The hydraulic motor is direct-coupled to the splined end of the pinion shaft *A*, Fig. 8, which drives a spur gear keyed to the shaft *B* of the lower box, the reduction ratio being 4·2 to 1. Drive is also taken from the pinion shaft, through 1·8 to 1 spur reduction gears, to a tacho-generator *C*, which is concerned with velocity feed-back in the servo system. The shaft *B* has ¾-in. of free axial movement in the three roller bearings wherein it is mounted, and solid with the shaft there are right- and left-hand, 45-deg. helical pinions, which mesh with the gears *D* and *E*. Drive is then taken through two spur gear reduction stages, and the overall ratio of the main gear box train to each rack pinion is 85·7 to 1. For a traverse speed of 120 in. per min., the rack pinion shafts rotate at 15·3 r.p.m., and provide for a maximum thrust of 4,000 lb., continuous rating. All the gears in the two boxes have hardened and ground teeth, and the rack pinion shafts, it will be noted, are supported in outboard needle roller bearings, as at *F*, to minimize deflection.

Axial loading of the shaft *B*, for the elimination of backlash in the system, through the medium of the helical gears in the two trains, is effected by applying air, at a maximum pressure of 58 lb. per sq. in., to the exterior of the non-rotating bellows unit *G*, which bears on the outer ring of an angular-contact ball race *H*, carried on the shaft. The total axial load applied is 150 lb., which results in a pre-load corresponding to 110 per cent of full load torque. Under conditions of no load, the pre-load torque is equally distributed through the two gear trains, and it is taken up by the train which is transmitting the drive, as the load is applied. At full load, the remaining 10 per cent of pre-load, exerted on the non-driving train, maintains back-lash free conditions.

A light compression spring *J* keeps the bellows

unit seated when there is no air pressure, and, under operating conditions, the axial movement of the shaft *B* is shown by a spring-loaded indicator rod *K*, which slides between upper and lower index marks on the guide bush. Although a total movement of ⅜ in. is provided for the shaft, the precision of the drive system is such that, in practice, the movement does not amount to more than about $\frac{1}{32}$ in. This figure, it will be appreciated is very small, taking into account the high ratio of the gear trains (85·7 to 1).

Particular care has been taken in connection with lubrication, which is effected by oil mist. The oil is drawn from a sump in the main gearbox into spray nozzles in the two gearbox sections, by the flow of compressed air at a pressure of 15 lb. per sq. in. A filter is provided at *L*, Fig. 7, on the side of the main box, which separates the used oil from the air and allows the latter to exhaust to atmosphere.

The tacho-generator *C*, carried on the input gearbox, protrudes into an enclosed, tubular compartment in the main gearbox, through which compressed air is circulated to prevent heat being conducted to the driving gear trains. Incorporated in the generator itself is a heating element which serves to maintain an even temperature, so that the electrical output is accurately linear.

For the spindle-head cross-traverse of 12 in., on the *z* axis of the machine, the ball circulating nut and screw employed are of 1½ in. diameter by ⅛ in. pitch. They were produced by the Fairey Aviation Co., Ltd., in conjunction with the Coventry Gauge & Tool Co. Ltd., who ground the screw threads. Backlash between the screw and nut is eliminated by making the nut in two parts, one of which is fixed axially, while the other is arranged to slide. A pressure of 1,000 lb. is applied between the two portions of the nut by means of a spring, which exerts a thrust in excess of the maximum feed pressure that is likely to be encountered in service. Details of the screw and nut assembly are given in Fig. 9.

Drive is taken through a double-train, backlash-free reduction gearbox of Ferranti design, of a type similar to that which has been applied by the latter company to the table of a tape-controlled C.V.A.-Kearney & Trecker knee-type milling machine, as described in MACHINERY, 88/451—13/4/56. For the latter application, however, the power was supplied by a direct-coupled electric servo-motor, instead of a Vickers-Detroit hydraulic motor, as on the machine here described.

The gearbox fitted to the knee-type milling machine is shown in Fig. 10, and the electric servo motor is seen at *A*. Loading of the two gear trains for the elimination of backlash is effected by means of the compression spring seen dismantled on the left, in conjunction with right- and left-hand helical gears and two co-axial bevel gears. The latter mesh with a bevel gear on the transverse output shaft which, on the Fairey machine, is connected to the ½-in. pitch lead screw, through a torque-limiting coupling. This coupling consists of a disc driving member, fitted with two diametrically-opposite, radial spring-loaded balls in the periphery, which engage V-grooves in the bore of a driving drum attached to the lead screw. All the shafts in the gearbox are mounted on anti-friction bearings, and the gears have hardened and ground teeth. Lubrication is effected by oil mist, the cast gearbox casing forming a sump. On continuous rating, a maximum cross traverse rate of 60 in. per min. is provided for the spindle head, and up to 90 in. per min. intermittently, for rapid return and setting.

The hydraulic motors for the three movements of the machine, on the *x*, *y* and *z* axes, are con-

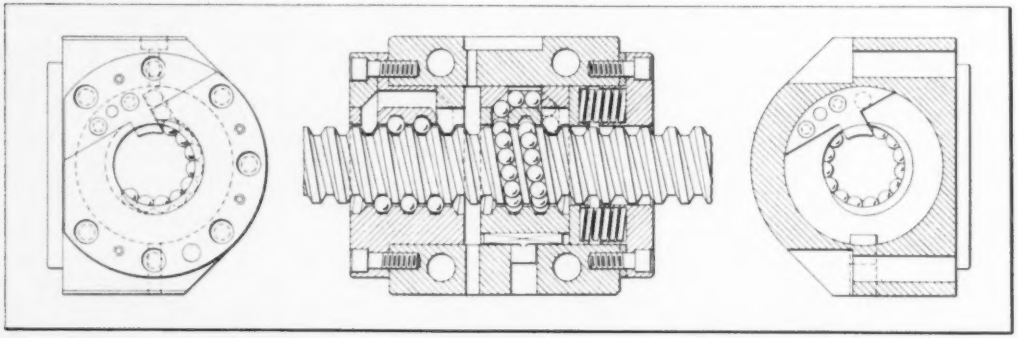


Fig. 9. Details of the Ball-circulating Nut and Screw Assembly

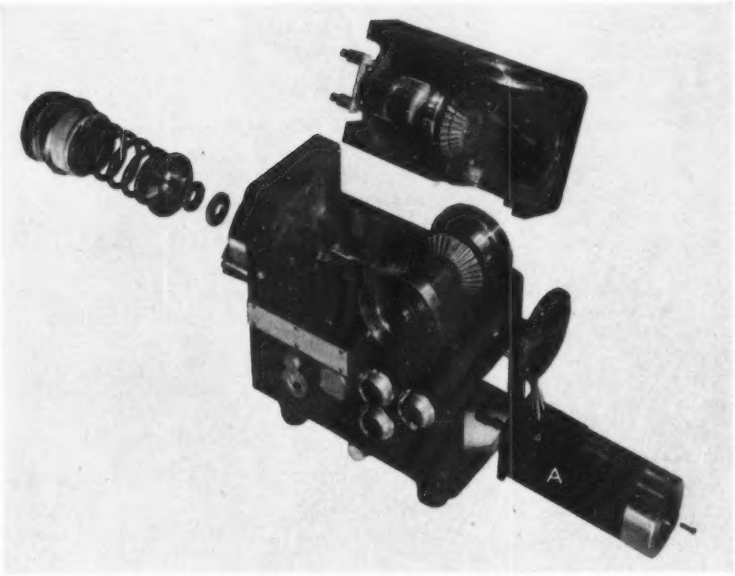


Fig. 10. A Double-train, Backlash-free Reduction Gearbox, of Ferranti Design, of a Similar Type to that Incorporated in the Fairey Machine

trolled by high-response piston valves, suitable for use at pressures from 100 to 3,000 lb. per sq. in. For the Fairey machine, the relatively high pressure of 2,000 lb. per sq. in. is employed, to enable compact hydraulic motors with low inertia characteristics to be fitted.

Hydraulic oil, at a pressure of 2,000 lb. per sq. in., is supplied by a Keelavite motor-pump unit, which, together with a frequency changer for the cutter spindle drive, is housed in a separate cubicle, away from the machine. Pressure, return, and drain pipes are taken, beneath the floor, to a manifold on the front of the bed, at the centre, to which the lubricating oil supply is also coupled, as previously described. This manifold is connected by flexible pipes, carried in a flexible armoured hose, to another manifold on the column saddle, and thence to the distribution panel seen, with the cover open, in Fig. 4. A trough at the front of the bed accommodates the armoured hose in a loop to provide for the traversing motion of the column. Incorporated in the hydraulic circuit is a Greer-Mercier hydro-pneumatic accumulator which serves to smooth the supply against sudden demands of the servo-system.

The electrical power supply, taken from a contactor cubicle supplied by Erskine Heap & Co., Ltd., also the electronic circuit cables from the tape reader, are carried to the column control panel by a swinging jib pivoted on a wall bracket.

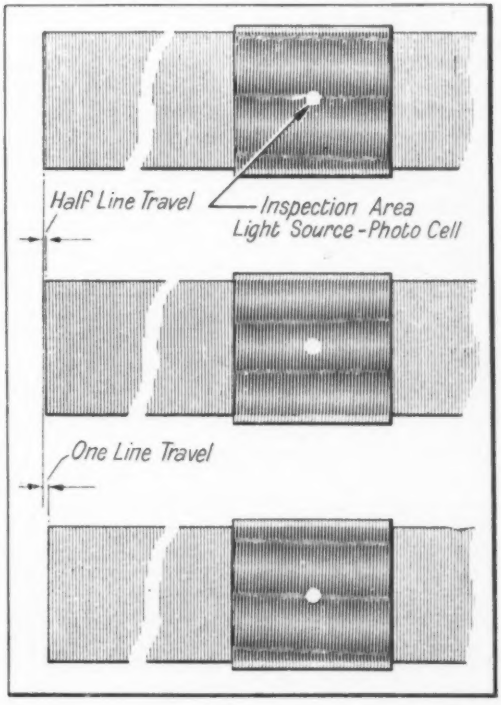


Fig. 11 (below) Diagram Showing the Application of Diffraction Gratings to the Measurement of Linear Displacements

CONTROL SYSTEM

The Ferranti system of machine tool control by means of a magnetic tape, prepared by digital computer techniques, has been the subject of several previous articles in MACHINERY, notably in 88/451—13/4/56. Briefly, the measuring element of the system is a length of diffraction grating carrying a precisely known number of lines to the inch, formed on a glass base. When two sections of such a grating are superimposed, as shown in Fig. 11, so that one is tilted with respect to the other, a moiré fringe pattern, with an approximately sinusoidal distribution of intensity, is produced.

When one grating is moved with respect to the other, in a direction at right-angles to its line structure, the fringe pattern travels at right-angles to the direction of relative travel of the gratings. A relative travel of one line width on the gratings will cause a complete cycle of light and darkness to pass a particular point, and the width of these light and dark bands can be made sufficiently great to permit detection of individual bands by the use of a photo-electric cell. If, therefore, the number of bands is counted, a precise measure of the amount of displacement of one grating with respect to the other can be obtained, with reference to the number of grating lines per inch. For example, when using gratings with 1,000 lines per inch, a travel of ½ in. will cause 500 interference bands to pass the point which is being observed, and the number of bands passing this point each second is a measure of the rate of relative travel.

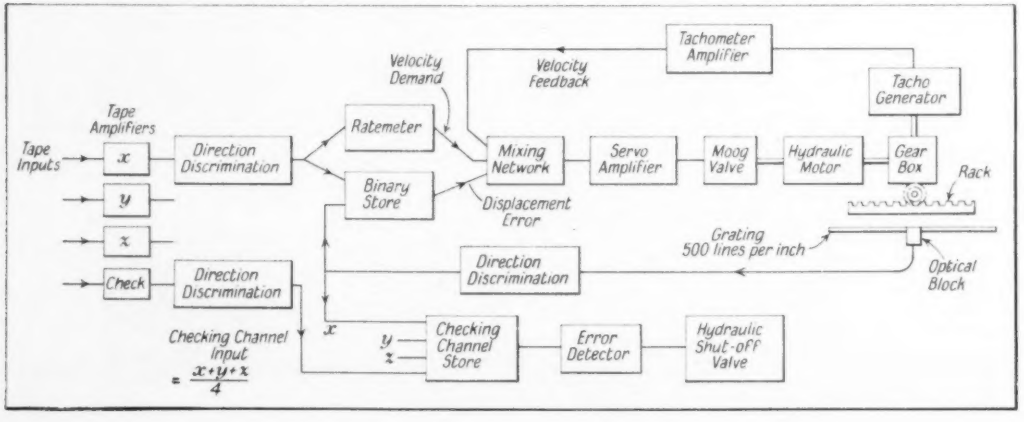
Electrical signals provided by the photo-cells give two pulses per grating line for the purpose of digital measurement. To permit discrimination of direction, two photo-electric cells are used, which inspect two points of the fringe pattern. These points are separated by an odd number of quarter wave-lengths of the pattern, and their outputs form a two-phase electrical system from which directional information is readily obtainable.

This measuring system has the advantage that it is entirely free from friction and wear, and since the interference pattern is obtained from a relatively large area of grating, lengths of grating can be placed end to end, with small gaps if necessary, provided, of course, that they are accurately phased. The absence of a few lines merely lowers the contrast of the pattern by a corresponding amount. For the same reason, the presence of dirt and scratches on the grating has little effect.

Acknowledgement is made to the National Physical Laboratory for their work in making these gratings avialable. An article describing methods developed at the NPL for the production of diffraction gratings was published in MACHINERY, 84/36—1/1/55. Ferranti Ltd., hold patents in connection with the application of the gratings in a measuring system. For this purpose, gratings with numbers of lines up to 5,000 per inch have been used, to provide a measuring accuracy of 0·0001 in.

Gratings employed on the Fairey machine have 500 lines per inch, and thus permit measurements to an accuracy of 0·001 in. For the bed and the column, 10-in. lengths are assembled, and for the spindle saddle, a single 17-in. length is employed. Referring to Fig. 2, the lengths of fixed diffraction grating, *H*, on the bed, are carried in a mild steel channel member *J*, against the vertical face of

Fig. 12. Block Diagram of the Elements of the Ferranti Tape Control System Employed on the Fairey Milling Machine



which they are held by a corrugated flat spring *K*. Anchorage is provided by a series of 0·015-in. thick leaf-springs, as at *L*, which are fastened to the top surface of the channel by screws. A steel end block is cemented with Araldyte to the under-side of each spring, and to the glass grating, at the centre.

The unit incorporating the short grating, photo-electric cells, and light source, is seen at *M*, mounted on a bracket attached to the under-side of the column saddle, protection being afforded by a sheet metal cover *N*, also by the bellows which cover the bedways. The arrangement of the gratings and photo-electric cell units of the column and spindle saddle are generally similar. There, protection for the gratings is provided by flexible steel bands which pass over rollers, and the ends of the bands are coupled together by springs. The column slideways are covered by a neoprene blind. Safety limit switches, it may be noted, are fitted to control the maximum traverse movements of the machine in the three directions.

A block diagram of the Ferranti control system is given in Fig. 12. The control unit for the machine, seen in the foreground on the right in Fig. 1, which incorporates the multi-channel tape readers, and other associated electrical equipment, is designed to withstand arduous workshop conditions, and is pressurized by filtered air to prevent the ingress of dust. Electrical maintenance is facilitated by a system of plug-in circuit cards, which can readily be removed from their trays, and replaced by others, should a fault develop.

Provision is made for fault detection by monitor cathode ray tubes, and the tolerances on individual circuits is such that, normally, no adjustments need be made to replacement units. A number of checks can be made throughout the various stages in the operation, including automatic continuous monitoring of the performance of the control unit and the machine tool. The control unit is equipped with means for reducing the supply voltage to each circuit card tray during the reading of a special tape. This marginal test will indicate any potentially defective units, which can then be replaced before a service failure occurs.

A system is also incorporated for protection of the entire equipment against incorrect operation from supply failure, or any other cause, when the machine is running. For this purpose, in addition to the *x*, *y* and *z* channels on the tape, a fourth channel is provided whereon a pulse train is recorded when the tape is being produced on the computer. The number of pulses on this channel is equal to the algebraic sum of the pulses on the *x*, *y* and *z* channels, divided by four. Circuits are included in the machine control unit which add the pulses received from the *x*, *y* and *z* measuring systems on the machine, and check that this algebraic sum, divided by four, corresponds to the pulse train of the fourth channel. Any fault is thus immediately detected, and should the cumulative discrepancy exceed pre-determined limits, the supply of pressure oil is rapidly cut off, by means of Dowty electrically-operated stop valves in the circuits of the hydraulic motors. The error detector in the checking channel can be set to operate the shut-off valves for an error of 0·008, 0·016 or 0·032 in., lasting for 100 milli-sec., or for an instantaneous error of 0·063 in.

An additional control is provided on the tape reader unit whereby the scale of the pulses derived from the tape can be changed automatically in the ratio of 2:1 to provide a fast feed rate when carrying out rough machining operations. Tapes can be used, which provide up to 48 min. running time, and upon completion of the machining sequence the tape reader stops automatically.

The controls on the operator's travelling platform on the machine column are centralized on a pillar-mounted panel, which can be hinged down to a horizontal position, as seen at *B*, in Fig. 6, so that the machine can be controlled from floor level, if desired. On this panel there is a 2-position switch for "servos on," and "servos off," and a 3-position switch provides for selecting "tape on," "manual slow," and "manual fast." Movements in each direction horizontally, vertically, and transversely, under manual control, are initiated by means of six push-buttons, and the sensitivity of the servo system is such that inching in increments of 0·001 in. can readily be effected when the selector switch is set to "manual slow." Since the servo and grating system is capable of holding the machine elements precisely in any rest position, accurate, machining operations can be carried out independently of the tape control, without the need for any means of slide clamping.

Under tape control, it has been found possible to achieve an accuracy of ±0·002 in. on all dimensions up to 18 in., with a repeatability of ±0·001 in., at a traverse rate of 50 in. per min.

SPINDLE HEAD DEVELOPMENTS

As already mentioned, the Fairey Aviation Co., Ltd., have carried out a considerable amount of development work on the high-speed milling of light alloys, and test equipment has been constructed to ascertain the effects of cutting speeds up to 12,000 ft. per min. There is no evidence, it is stated, that such speeds approach a maximum. Tungsten-carbide cutters with spiral blades are considered essential, and an efficient coolant system

is necessary to overcome the problem of chip welding. Cooling by directing a jet of fluid on to the cutting edges has not been found satisfactory, since the coolant is flung off by centrifugal force. Success is achieved, however, by generating a coolant mist and passing it through the centre of the spindle, whence it is directed on to the cutting edges by way of holes in the cutter body, adjacent to the blades.

A spindle head incorporating this type of coolant system is fitted to the recently-constructed tape-controlled machine. It incorporates precision, pre-loaded anti-friction bearings, and is driven direct by a built-in B.T.H. stator-rotor unit of 10/20 h.p. the associated frequency changer providing speeds of 3,000 and 6,000 r.p.m. The cutters, it may be noted, are held in Clare collets, which ensure the necessary tight grip. Later developments include a spindle head fitted with the hydrodynamic oil-lubricated plain bearing developed by the Glacier Metal Co., Ltd., and a hydrostatic air bearing spindle head has also been built and is undergoing test. Air is admitted to this bearing at a pressure of about 120 lb. per sq. in., after it has passed through a Fairey Microfilter. When cutting operations are performed on high-strength light alloys on the new machine, a metal removal rate of 110 cu. in. per min. has been achieved, using an end mill of 2 in. diameter. For face-milling operations, the metal removal rate was 140 cu. in. per min. The traverse rate employed was 110 in. per min., and surface finishes of 10 micro-inches R.M.S. were obtained.

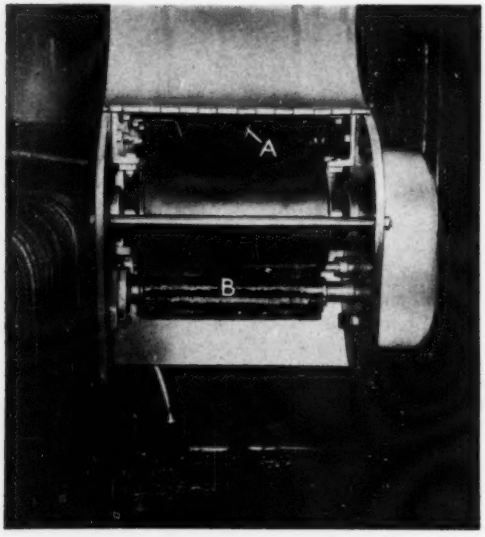


Fig. 12. View of the Delivery End of the Swarf Conveyor, with the Cowl Raised

Because of the freedom of movement of the sliding members, only a fraction of the full power that is available from the hydraulic traverse motors is required.

The weight of the spindle saddle on the column is balanced by means of a hydraulic piston and cylinder, to the upper end of which oil is supplied by way of a reducing valve. Upon the upward stroke of the piston, as the saddle moves down, the oil is exhausted through a spring-loaded relief valve. The load-carrying roller chains on the saddle pass over sheaves on the column, and under sheaves on the end of the piston rod, the cable end being anchored to the top of the column. A 2 to 1 ratio is thus obtained, which has enabled a hydraulic cylinder of short stroke to be employed.

TABLE AND WORK MOUNTING

The 28- by 8-ft. T-slotted work table is made up of four 14- by 4-ft. sections, and is foot-step mounted on three substantial columns, which are bolted to extensions of the main bed at the rear. The weight of this complete table and support assembly is 26 tons. Provision has been made for moving the columns back, if increased depth capacity is required for the machine.

A neoprene belt conveyor is provided at the foot of the table, alongside the bed, for disposing of the large quantities of swarf that are produced during the maching operations. Hinged aluminium tread plates are fitted, which serve as swarf deflectors when raised, as seen in Fig. 1, and form a walk-way over the conveyor, when lowered, to facilitate loading and unloading the work. A view looking along the conveyor from the delivery end is given in Fig. 13, from which it will be seen that the belt runs between side guide plates as at *A*, whereby it is formed into a trough to provide increased carrying capacity. The flanged driving and idler pulleys are flat faced, and, at the delivery end, the belt is cleaned by a rotating brush *B*.

The workpiece seen on the table in Fig. 1 is one of the main wing spars for a Fairey Gannet naval aircraft, and it is being machined from a 20-ft. by 3-ft. by 3-in. thick stretched slab of aluminium alloy. The weight of the latter is initially 1¼ tons, and the finished piece weighs only 240 lb., so that about 90 per cent of the material is reduced to swarf and scrap sections of slab. This component, which has web thicknesses as small as 0·080 in., is the first of any appreciable size that has been handled on the new machine.

Reference has been made in previous articles to the methods of programming applied in connection with magnetic tape control. The various dimensions of the component are specified from x, y, and z axes, and these dimensions are expressed in decimal fractions. The points of change from one curve or straight line to the next are specified, and a simple table is prepared giving the *x*, *y*, and *z* co-ordinates for the various change points. From the drawing, and information concerning cutter diameter and feed rates, a planning sheet is compiled, for which a system of symbols is employed. In addition to straight lines and circles, an ellipse, parabola or hyperbola can be directly specified by a symbol, and other curves can normally be expressed in terms of ordinates. From the planning sheet, a punched paper tape is very simply produced in the planning office by copy typing on a Creed teleprinter. It is this paper tape that serves as the injut to the electronic computer which produces the magnetic tape used for controlling the machine tool. Ferranti, Ltd., have organized a computer service for the preparation of magnetic tapes from users' punched paper tapes, at little expense.

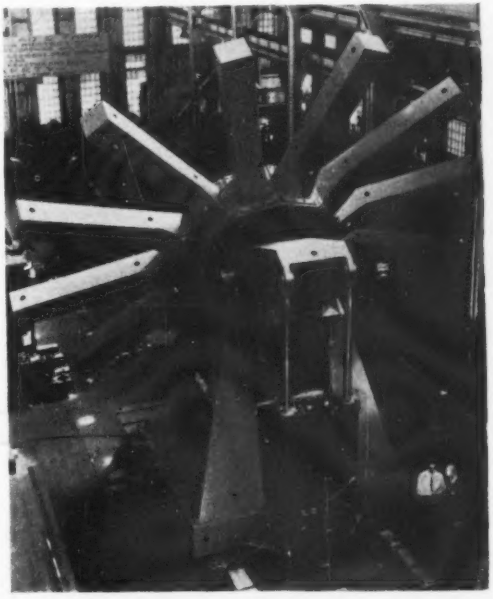
The time required for producing the Gannet wing spar under tape control is estimated at about 20 hours, exclusive of programming, whereas on a conventional routing machine, using a series of templates, the operation would take approximately eight weeks. With properly prepared drawings, programming can be carried out in appreciably less time than is required to make router templates. One magnetic tape, it may be noted, can be used to produce similar workpieces with right- and left-hand forms.

For initially setting the spindle axis of the machine, so that it coincides with the established co-ordinate datum point of the workpiece, before the tape control is brought into operation, a large-diameter location pin, mounted on a base, is clamped to the table in the correct position relative to the work. A sliding sleeve is applied over the location pin and spindle nose to check the alignment. The *z* axis datum setting, which concerns depth of cut, is obtained by the use of a thickness gauge between the face of the milling cutter and the ground end face of the location pin. Machine movements, under tape control, can readily be checked, before machining is started, by mounting a pencil or scriber in the spindle nose, in place of a cutter, and then marking out the workpiece blank.

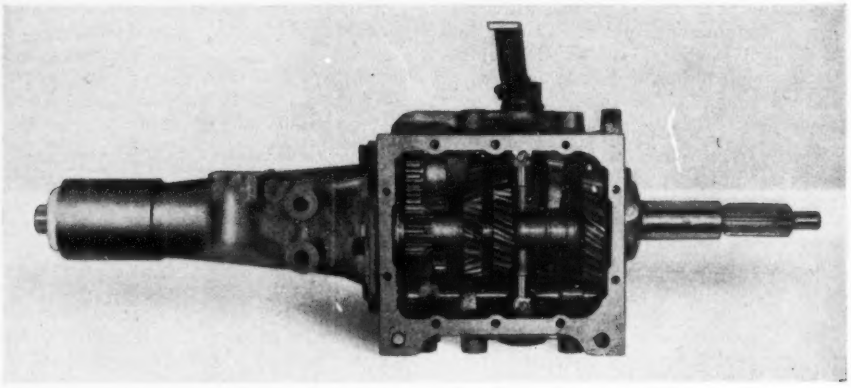
Large Welding Positioner

The welding positioner shown was recently supplied by the Pandjiris Weldment Co., 5151 Northrup Avenue, St. Louis, 10, Missouri, U.S.A., to the Mare Island Naval Shipyard, Vallejo, California. Claimed to be the largest unit of its type so far constructed, this positioner weighs 100 (short) tons, and has an overall height of 20 ft. 10 in. with the table in the horizontal position. Made in the form of a rimless spoked wheel, with a hub of 11 ft. diameter, the table has a diameter of 33 ft., and there are T-slots in the face of each spoke, for work clamping. Two hydraulic cylinders are provided for tilting the table to any angle from the horizontal to 60 deg., and are supplied by a pump driven by a 25 h.p. motor. The table can be tilted, between the limits stated, in 4 min.

Loads up to 75 (short) tons can be carried on the table and it can be rotated at a fast traverse rate of 0·2 r.p.m., for initial positioning by means of a 7½-h.p. motor. For welding, the table is driven by a variable-speed motor of 2 h.p. which gives speeds from 0·052 to 0·0052 r.p.m., the lowest speed being equivalent to one complete revolution in 3 hours 10 min. After being tested, the positioner was dismantled for delivery by road.



Claimed to be the Largest Yet Built, this Welding Positioner Weighs 100 (short) tons



Producing the Vauxhall Victor

Methods Employed by Vauxhall Motors, Ltd., Luton

In an article which was published in MACHINERY, 92/760—4/4/58, the Vauxhall Victor 4-seater, 1⅝-litre passenger car was briefly described, the new features of its mechanical units were discussed, and details were given of the machines and methods employed for the operations on gearbox castings, including a large Snyder 53-station transfer machine. Although the machines employed for other gearbox parts are not so impressive as this transfer machine, they nevertheless present many interesting features, and some typical operations on front covers, and rear extensions, main-shafts, clutch hubs, and striking forks and levers, are here discussed. As explained in the earlier article, the gearbox employed for the Victor has a main casting of approximately rectangular box-shape. To the end faces of this casting are secured the clutch housing and the rear extension, and, for ease of assembly, the front end of the main drive pinion is supported in bearings in a mushroom-shaped component known as the front cover, which is spigot-located in a bore in the front face of the casting, within the clutch housing, and secured by five bolts.

OPERATIONS ON THE FRONT COVER

A view of an assembled gearbox, with the bottom cover removed to show the internal mechanism, is given in the heading illustration, and the front cover, which is a grey iron casting, is seen at the right end, with the stem enclosing the main drive pinion almost up to the driving splines. A drawing of the front cover showing the principal dimensions is given in Fig. 1. The initial operations on the casting, after it has been shot-blasted, are carried out on a pair of Wickman chucking automatics, of which the first is of 6⅝ in. capacity and has six spindles. In this machine, the casting is held by the stem and located endwise from the rear surface of the flange, while the outside diameter, the stepped portion, and the joint face are semi-finish turned; the inside of the head and the small bore are machined; the end and the 1·4-in. diameter boss are faced; and internal and external chamfers are formed. On the second automatic, which is of 5 in. capacity and has five spindles, the casting is gripped on the outside diameter and located endwise from the machined face while the stem is turned, leaving an allowance for grinding. In addition, the stem is core-drilled and bored 1·005/1·010 in. diameter, the end is faced and chamfered, and the undercut adjacent to the head of the component is produced.

The castings then pass to an Alfing (Associated Alfing Kessler, Ltd.) fine boring machine, a general view of which is given in Fig. 2. This machine has three spindle heads mounted on a slide, each driven, by a separate 3-h.p. motor through V-belts, at a speed of 332 r.p.m. The slide carrying the spindles can be traversed towards and away from the tooling at the front

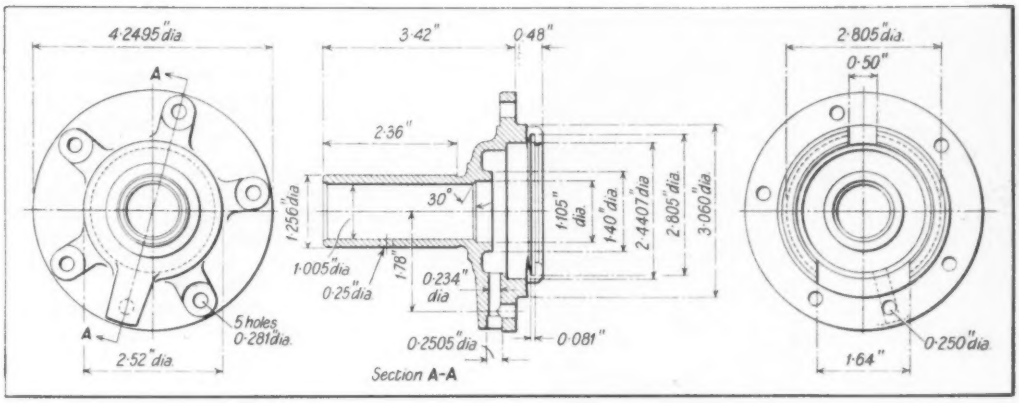


Fig. 1. The Front Cover for the Vauxhall Victor Gearbox, which Houses the Ball Race at One End of the Main Drive Pinion

of the machine at fast or slow rates by hydraulic cylinders. When facing or similar operations are to be performed, the points at which the slide is stopped are determined by accurate length bars carried in a hydraulically-indexed drum beneath the table. Each spindle has a collet chuck, which is closed by a hydraulically-operated draw-bar controlled by push-button from the front of the machine, and the casting is held by the stem diameter and located by the end of the stem, which is held in contact with a stop. Three sets of tooling are carried on the machine table in front of the spindles, and this table can be moved sideways hydraulically, under the control of limit switches operated by adjustable dogs.

A close-up view from directly overhead showing the arrangement of one of the sets of tooling is shown in Fig. 3. In each set, there are two holders, one of which carries four tools, and the other, three, and provision is made for each holder to be adjusted towards and away from the spindle in 0·001-in. increments. With one exception, all the tools in each set are of the Microbore design (Alfred Herbert, Ltd.), so that they may easily be adjusted. Originally, two sets of tools were provided for the machine, and it was intended that they should be removed complete in the holders for sharpening, pre-set with the aid of special gauges, and replaced when the other set became blunt. Difficulties were experienced with this procedure, however, due to the fine limits specified, and, in view of the ease and accuracy with which

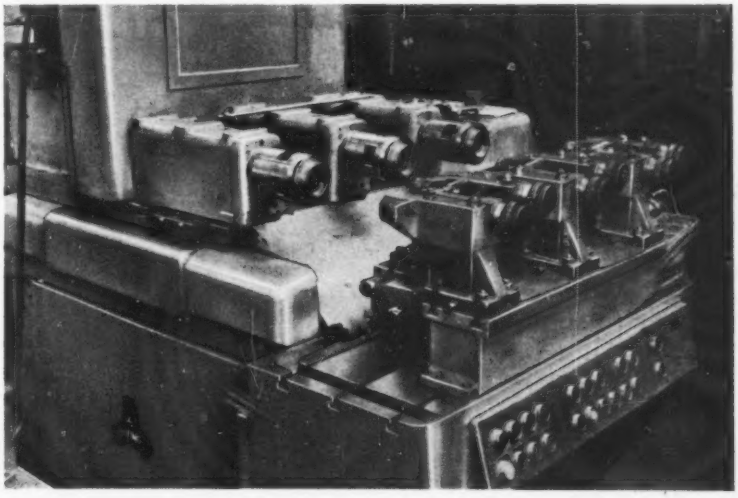


Fig. 2. Set-up on an Alfing Fine Boring and Facing Machine for Finishing Operations on the Gearbox Front Cover Casting. The Collet Chucks in which the Castings are Held are Operated Hydraulically

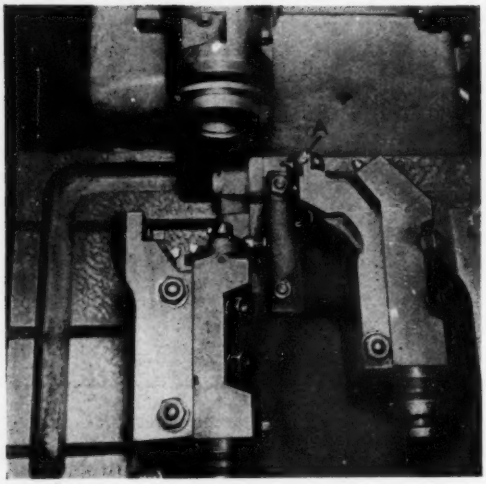


Fig. 3. Close-up Overhead View of One of the Three Sets of Tooling on the Alfing Machine. The Holders on the Left and Right are Equipped with Four and Three Tools Respectively

the tools in the Microbore holders can be adjusted, each is now re-set individually after it has been sharpened. The machine cycle is entirely automatic after the work has been loaded, the collets closed, and the start button pressed. The slide carrying the spindles moves forward at the first rate of traverse, and, as the components approach the tools, the spindles are started and the slow feed rate of 2·27 in. per min. is automatically engaged. The four tools at the left in Fig. 3 then turn the outside of the head and the spigot, machine the large bore and the enlarged diameter at the end of the stem bore, and form the adjacent 30-deg. seat.

Next, the spindle-head slide is retracted slightly to align the components with the set of three tools at the right, one of which is carried in the end of the projection *A*, and cannot be seen. For the second part of the operations, the spindle slide remains stationary and the table carrying the tools is traversed to the left at the rate of 1·8 in. per min. During the first part of this movement, the tool-bit at the extreme right faces the outer flange, and the tool in the end of the holder *A* then comes into operation to face the end of the internal projection. At about the same time, the thin blade-type tool in the left-hand side of the holder *A* is plunged into the side of the large bore to cut the 0·081/0·076-in. wide groove. In the final assembly, the spigot engages a hole machined in the front face of the gearbox casting to locate the front cover, and the outer race of a ball bearing carrying the gearbox mainshaft is pressed into the large bore. The bearing race has an external groove to match the groove in the large bore, and a retaining ring is fitted in these grooves to hold the race in position. Location of the front end of the gearbox mainshaft depends on the accuracy with which the operations on the Alfing machine are carried out, and a special Solex inspection unit is employed for a 100 per cent check of the castings after the stem has been ground.

After fine boring, the castings are passed to a row of machines on which they are held in simple fixtures while an oil circulation hole is first drilled 0·234 in. and then reamed 0·2495/0·2505 in. diameter at 90 deg. to the stem, and the 0·25-in. hole is drilled in the stem. The five 0·281-in. diameter holes in the flange are then drilled, together with the communicating oil circulation hole of 0·25 in. diameter, and the five bosses at the rear of the flange are spot-faced. Two slots, 0·5 in. and 1·64 in. wide, are then milled, and finally the stem is finish-ground to a diameter of 1·255/1·256 in.

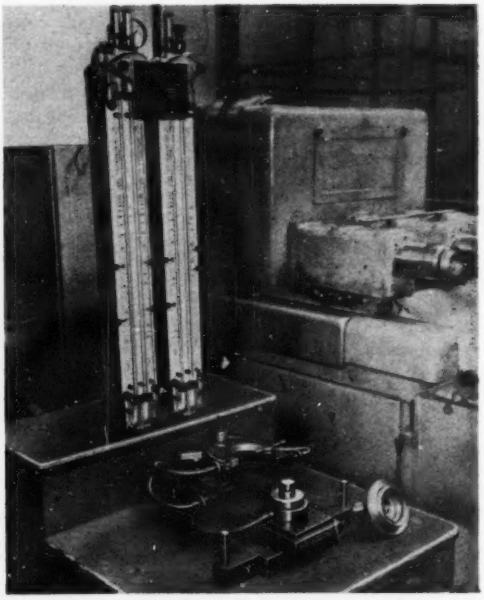


Fig. 4. For Checking One Internal and Three External Diameters on the Gearbox Front Cover this Solex Pneumatic Unit is Employed. The Manometer Tubes are Graduated in Divisions of 0·0001 in.

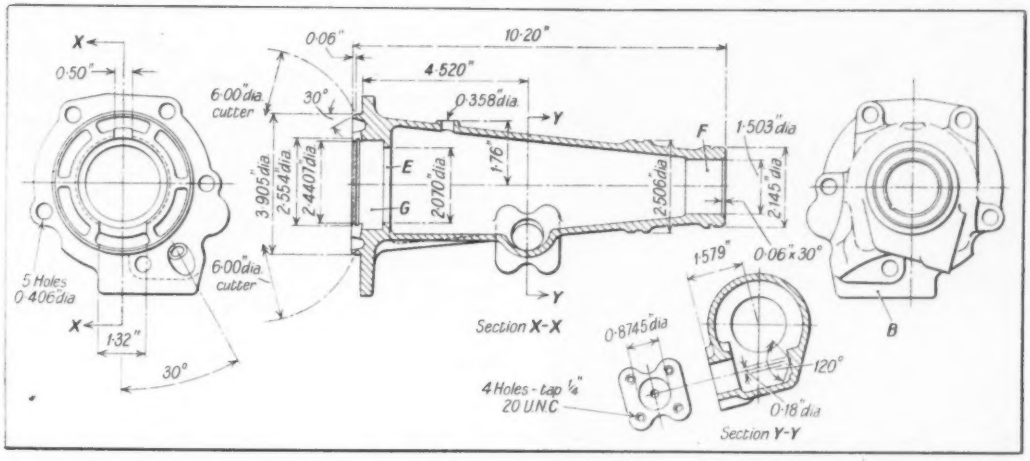


Fig. 5. The Gearbox Rear Cover Casting Houses the Ball Race for the Rear End of the Mainshaft, also the Speedometer Drive

Inspection by means of the special Solex unit follows. This equipment is shown in Fig. 4, and there is a stepped projection incorporating measuring jets whereby the diameter of the bearing race bore, which must be held to 2·4413/2·4407 in., is measured and registered on the right-hand manometer tube, the latter being graduated in divisions of 0·0001 in. This locating projection for the casting is mounted on a slide, so that it may be pushed towards the rear with the aid of the handle at each side, and the outside, spigot and stem diameters, are then engaged by caliper type gauges. These gauges incorporate measuring heads with plungers which are moved against light spring pressure and vary the size of air jets connected to the manometer tubes. The outside diameter of the head is held to 4·2485/4·2495 in., the spigot to 3·059/3·060 in., and the stem to 1·255/1·256 in., all the tubes being graduated in 0·0001-in. divisions. In addition, the component is turned by hand so that the squareness of the flange face with the bearing bore and the outside of the stem, which must be within 0·002 in. total indicator reading, may be checked. Other requirements which are verified at this stage are that the outside of the head and the spigot diameter should be concentric within 0·001 in. and that stem bores should be concentric with the bearing bore within 0·003 in. total indicator reading.

After the inspection stage, the finished castings are loaded on to hangers suspended from an overhead conveyor, and are carried through a mechanized washing unit to the assembly line.

MACHINING THE REAR EXTENSION

The outside shape of the gearbox rear extension and the position which it occupies in the completed assembly may be seen from the heading illustration, and in Fig. 5 some of the main dimensions are indicated. Before the grey iron castings enter the machine shop, they are shot-blasted internally and externally in a special Spenstead (Spencer & Halstead, Ltd.) plant. This plant, and another for the gearbox castings, are installed in the same room, and they are served by common dust-extraction and shot-storage units. A view of the Spenstead plant for rear extension castings is given in Fig. 6, where a casting is being loaded into one of the positioning fixtures which are carried on a continuously-revolving circular table. No clamps are employed on the fixtures, and the casting rests on the flange at the large end, location being provided by the cast spigot which enters a hole, and is supported in the upright position by rubber-protected V-surfaces which embrace the small end near the top. As the table slowly turns, the castings are carried through sheet-rubber doors into the annular blasting chamber where nozzles are arranged both above and below the table to ensure that all the surfaces of the castings are treated. A bucket elevator system returns spent shot to the hopper above the chamber, after it has been screened to remove broken particles and foreign matter.

From the shot-blast room the castings are transported directly to a duplex trunnion-type boring,

Fig. 6. Internal and External Surfaces of the Rear Cover Castings are Shot Blasted in this Special Spenstead Machine. The Components are Carried Past Nozzles Above and Below the Table

facing and chamfering machine, a close-up view of which is given in Fig. 7. Built by Standard-Modern Tool Co., Ltd., Toronto, Canada, who are associated with James Archdale & Co., Ltd., in this country, the machine is one of several supplied by the Canadian Company for machining Victor components, and it incorporates some hydraulic units made by the British firm. This machine has a 4-station indexing fixture, which is turned through 90 deg. at each cycle by a hydraulic cylinder at the rear. Loading is carried out at the station at the front in Fig. 7, and each component is positioned with the projection *B*, Fig. 5, of the large flange, upwards. The handle *C* is then turned to the right to operate a plunger which applies pressure to the lower portion of the large flange. The opposite face of the flange is thus held in contact with a stop while a Consolidated-Pneumatic nut-runner, suspended above the machine, is applied to tighten the hexagon-headed stud *D*. This stud has threads of opposite hand and when it is turned, two jaws held in vertical guideways, are brought together to grip the small end of the casting between V-surfaces. A dog-type clamp is then applied to the top of the flange at the large end of the casting, and the handle *C* is moved to the left, to withdraw the plunger and operate a limit switch. A circuit is thus completed which permits the automatic machine cycle to be started.

Unit heads, each with three spindles, are carried on ways at each side of the fixture, and the tools operate on the casting through heavy bush-plates. For the large end of the casting, the spindles are driven by a 15-h.p. motor, and for the small end, by a 7·5-h.p. motor. The heads are traversed hydraulically, fast and slow movements being automatically engaged by dogs which operate limit switches on the base at each side. When the automatic machine cycle is initiated by pressure on one of the buttons on the panel at the right in Fig. 7, the fixture is first indexed so that the casting at the loading station is moved upwards, and a completed casting is brought to the loading station so that re-loading can begin. The first machining

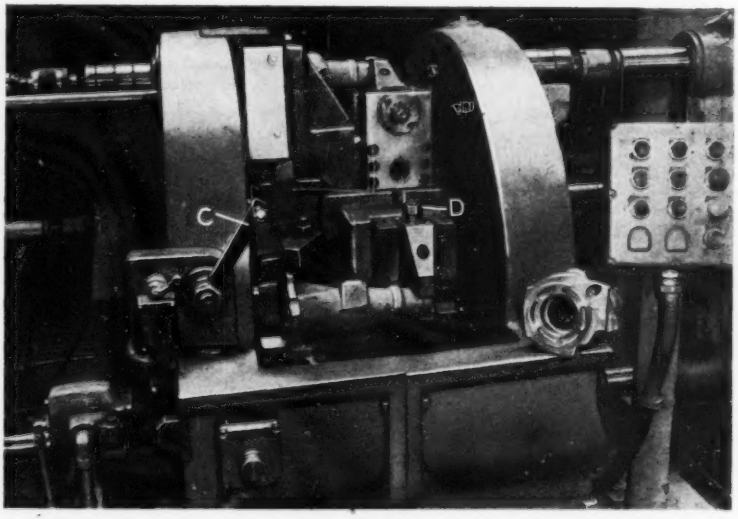


Fig. 7. Preliminary Machining of the Rear Extension Castings is Carried Out on this Standard-Modern Duplex, Trunnion-type, Boring, Facing, and Chamfering Machine, at Three Stations

station provides for finish-boring the 2·070/2·086-in. diameter bore *E*, Fig. 5, at the large end, and for rough-boring the diameter *F* at the small end. At the second station, both ends of the casting are faced and chamfered internally, and at the third, the bores *G* and *F*, Fig. 5, are semi-finished. For these operations, cutters with four inserted carbide-tipped serrated blades are employed, and a dwell of about 5 sec. is provided to ensure that smooth surfaces are produced by the facing cutters. A spindle speed of 350 r.p.m. and a feed rate of 1¼ in. per min. are employed on this machine, and an output of about 87 castings per hour is obtained at 80 per cent efficiency.

The castings are next passed to a pair of similar Maximatic multi-tool lathes on which they are held internally by the bore *G*, located endwise from the face at the end of this bore and supported by a centre in the small end. With this set-up the large-end flange is semi-finish faced and the spigot turned and chamfered, also three diameters at the small end are semi-finish turned, and the end is chamfered. A special Standard-Modern machine is then employed to drill five 0·406-in. diameter bolt holes in the flange. One of these holes is produced with a drill-reamer in order that it may be employed for location purposes at later operations. In addition, a ⅜-in. diameter oil circulation hole is drilled at an angle of 45 deg. to the face, and a breather hole of 0·358/0·359 in. diameter is machined in the top of the casting with a drill-reamer.

Subsequently, the castings pass to another Standard-Modern machine, shown in Fig. 8, for operations on the speedometer drive housing. This machine has 12 stations on the table, one of which is employed for loading, the casting being positioned by the spigot and the bolt hole at the large end. A plug is then advanced into the small-end bore by turning the ball-handled lever at the outer end of the fixture, and serves to locate this end and to clamp the casting in position. The table is indexed in a clockwise direction, as viewed from above, and after the casting has passed an idle station, the first operation provides for drilling the speedometer drive housing, seen in the section *YY*, Fig. 5, $\frac{31}{32}$ in. diameter, and centring the internal face. At the fourth station, the flange face is machined by a facing cutter piloted in the previously-drilled bore. This bore is opened out to $\frac{33}{32}$ in. diameter at the fifth station, and, in addition, the face which was centred at station 3 is finish-machined. The housing bore is semi-finish reamed to $\frac{41}{64}$ in. diameter at station 6, and at stations 7 and 8 the four holes in the flange are drilled $\frac{13}{64}$ in. diameter. These holes are countersunk at the next two stations, and all the tools so far

Fig. 8. A Standard-Modern 12-station Machine is Employed for a Series of Drilling, Spot-facing, Reaming, Countersinking and Tapping Operations on the Speedometer Housing

mentioned are accommodated in the multi-spindle attachment carried on the large head at the centre in Fig. 8. The small head on the right has 4 spindles, and these provide, at stations 11 and 12, for tapping the flange holes ¼ in. by 20 U.N.C. 2B, to a depth of 0·40 in.

A special 3-way Kearney & Trecker machine built by C.V.A. Jigs, Moulds & Tools, Ltd. [E. H. Jones (Machine Tools), Ltd.] is next employed to face the areas surrounding the five bolt holes at the rear of the large-end flange. A close-up view of this machine is given in Fig. 9, and a central bed carries a pneumatically-operated clamping fixture in which the casting is spigot-located and angularly positioned by the reamed bolt hole. The casting is lowered over a vertical draw-bar, and a C-washer is then fitted between the small end and the draw-bar nut, before a valve is operated to admit air to the clamping cylinder. As will be seen from Fig. 9, the rear head has only one vertical spindle, which is fitted with a 6-in. diameter Galtona (Richard Lloyd, Ltd.), inserted blade carbide-tipped milling cutter with 18 teeth. This cutter is driven at a speed of 148 r.p.m., and is employed for facing the raised part of the

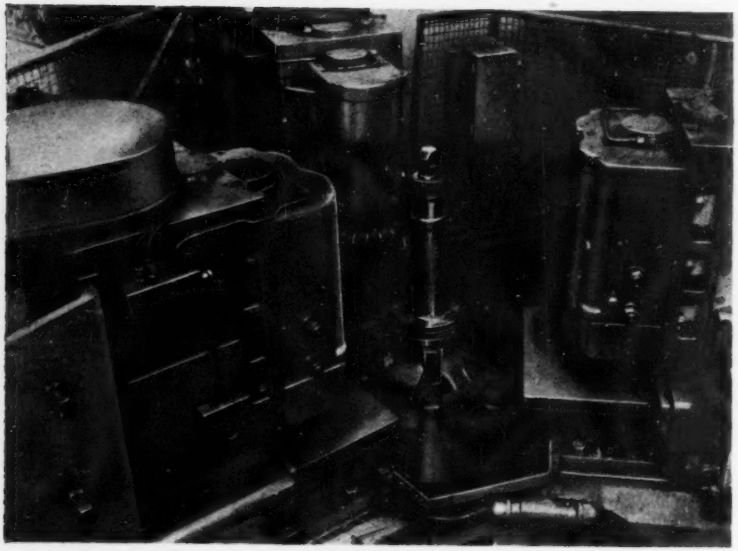


Fig. 9. On this Special, 3-way, C.A.V.-Kearney & Trecker Machine, the Areas Surrounding the Bolt Holes on the Rear of the Mounting Flange are Milled Simultaneously by Five Cutters

flange *B*, Fig. 5, surrounding the bolt hole on that side. The other two heads are of two-spindle design, and each spindle is fitted with a 4-in. diameter Galtona cutter with 12 carbide-tipped teeth and is driven at 220 r.p.m. The spindles are so arranged that the cutters face adjacent areas on the rear of the flange surrounding the bolt holes. Each head is driven by a 3-h.p. motor, and the radial feed rate is 3 in. per min.

After the boss surfaces have been milled, the small end bore is finished to 1·503/1·504 in. diameter on a Precimax (John Lund, Ltd.) fine boring machine, on which the casting is located from the 30-deg. chamfers on the spigot and the small end. A semi-circular slot inside this bore is then broached on a Weatherley Oilgear machine, after which a Vandervell wrapped steel bush lined with white metal is inserted on a 12-ton capacity Hi-Ton [Drummond Asquith (Sales), Ltd.] press. The bush, and the bore *G*, Fig. 5, are then fine-bored on the Ex-Cell-O duplex machine shown in Fig. 10, which also finishes the face at the end of the bore *G* and cuts the internal circlip groove. Two similar fixtures are provided, and each casting is loaded with the external chamfer on the spigot at the large end engaging a corresponding tapered surface in a bush, so that the bore is centrally located. At the other end, the casting is temporarily supported on V-surfaces at the top of a pillar until one of two buttons at the right is pressed to apply clamping pressure. The

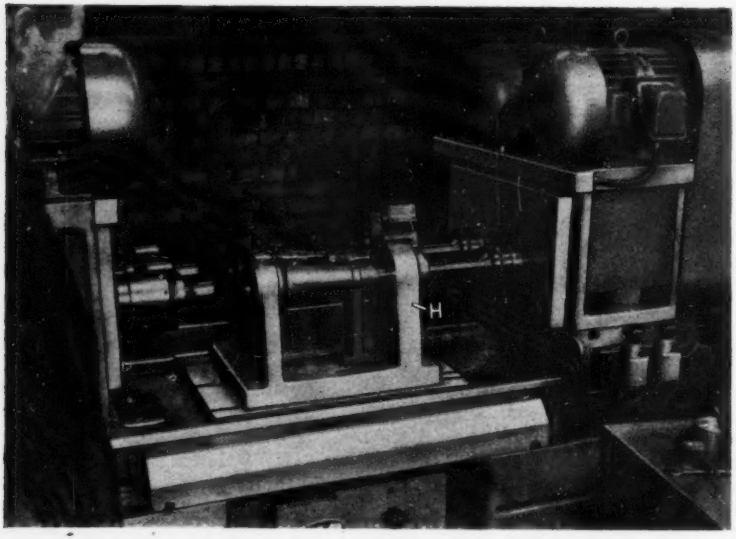


Fig. 10. Ex-Cell-O Duplex Machine for Fine-boring the Bearing Diameter, Facing the Mounting Flange, and Plunge-cutting a Circlip Groove

fixture projection *H* at the right of the castings carries two short-stroke hydraulic cylinders, the rams of which are hollow. On the side nearest the castings, the cylinder rams have coned bores, and when the appropriate button is pressed, oil is supplied to the annular piston in each cylinder. The ram is thrust to the left and the cone engages the 30-deg. chamfer on the small end of the casting, centring this end and applying the clamping pressure. Micro-switches mounted on top of the projection *H* are operated as the rams move into the clamping position so that circuits are completed which permit the machine cycle to proceed automatically.

The table on which the fixture is carried is fed first to the right, and the bushes in the small-end bores of the castings are finished to 1·3770/1·3785 in. diameter. For this operation, the spindles are driven at 2,400 r.p.m. by separate 3-h.p. motors, and when the tools have passed through the bushes, the spindles are stopped and the table is fast traversed to the left. The tool-bit for machining the large bore is carried in a bar which is mounted on the facing slide, and this slide is returned automatically to the central position after each operation. After finishing the spigot bore *G*, Fig. 5, to a diameter of 2·4407/2·4413 in., the table is stopped while the slide is fed radially for facing the surface at the end of the bore. Towards the end of this operation, a blade-type tool carried on the opposite side of the head comes into contact with the bore to plunge-cut the internal circlip groove to a width of 0·087/0·091 in. and a major diameter of 2·554/2·564 in. When the groove has been completed, the slide is retracted, the spindle is stopped, and the table is fast traversed to the position shown in Fig. 10, for reloading. For the large bores, a spindle speed of 150 r.p.m. is employed and the spindles are driven by 2-h.p. motors.

Two slots, one 1·32 and the other 0·5 in. wide, are next cut in the spigot at the large end, with 6-in. diameter cutters on an Archdale 28-in. horizontal machine. Subsequently another Ex-Cell-O fine boring and facing machine is employed to finish the face of the flange surrounding the spigot at the large end, turn the spigot diameter to 3·904/3·905 in., and finish turn two outside diameters to 2·504/2·506 and 2·143/2·145 in. at the small end. A breather vent is then fitted in the 0·358-in. diameter hole at the top of the casting, and finally the speedometer housing is fine bored to 0·8745/0·8757 in. diameter on a Precimax machine. The limits for concentricity of the large and small end bores, and for squareness of the face of the large end flange with these bores, are similar to those specified for the gearbox front cover, since the bore *G* forms a bearing housing for the gearbox mainshaft. After inspection, the castings are hung on a conveyor which carries them through a washing machine to the assembly track.

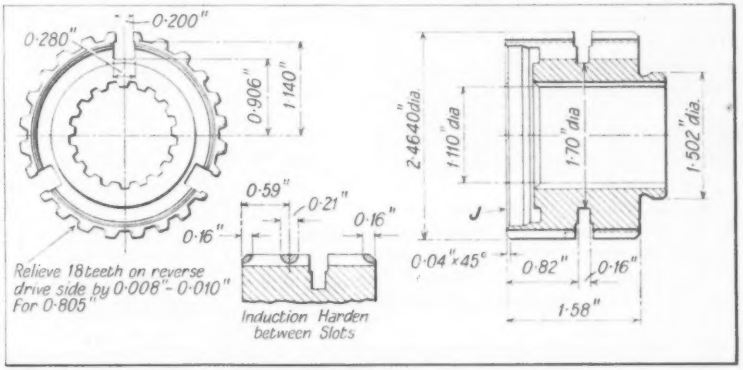


Fig. 11. The First and Reverse Speed Clutch Hub which Forms Part of the Synchromesh Mechanism for Engagement of First Gear

PRODUCTION OF SYNCHROMESH CLUTCH HUBS

As was explained in the first article in this series, the Victor gearbox incorporates a synchromesh mechanism for the first gear in addition to the normal provision for easy engagement of second and third gears. This first gear synchromesh mechanism incorporates a clutch hub with internal and external splines, which is mounted on a splined portion of the mainshaft, and carries the first gear clutch. The reverse gear teeth are cut on the outside of this clutch member, and between the clutch and the hub, in three equally-spaced slots in the latter, there are sliding keys. When the clutch is moved to engage first gear, while the car is moving, these keys are first pressed against a synchromesh cone which is thus pushed into engagement with a matching cone on the end of

one of the constant-mesh first speed gears. The clutch is thus speeded up, so that engagement of the clutch dog teeth with those on the gear is effected smoothly and silently. Views showing the form and principal dimensions of the first- and reverse-speed clutch hub, which is made from medium-carbon steel bar of 2⅝-in. diameter, are given in Fig. 11. The first operation is carried out in the bar shop on a 2⅝-in. capacity, 6-spindle Cone automatic (Charles Churchill & Co., Ltd.), and comprises drilling, counter-boring, chamfering, and parting off, approximately $\frac{1}{16}$ in. minimum of material being left for removal at later operations. The blanks are next hardened and tempered, to obtain the required grain size and structure, and are then shot-blasted in a Tilghman Wheelabrator plant before they are delivered to the machine shop.

Here, the blanks are placed in the magazine of an automatically loaded B.S.A.-Acme-Gridley 6-spindle automatic chucking machine, as shown in Fig. 12. The operations carried out on this machine, in a cycle time of 57 sec., comprise loading the piece into the 3-jaw chuck; boring the hole with an allowance on diameter for removal when the internal splines are broached; counter-boring, recessing and chamfering the face *J*, Fig. 11, which is termed the rear face because of its position in the final assembly; chamfering the outside diameter; and rough-turning the circumferential groove. For these operations, high-speed steel tools are employed at a spindle speed of 165 r.p.m. and a feed rate of 0·012 in. per rev. Automatic loading and unloading is carried out by the attachment shown in Fig. 12, which incorporates two air cylinders.

One of these cylinders, *K*, is secured at the front end to a bracket which is fitted to the tool cross-slide for one of the spindle positions so that it is carried in and out during the machine cycle. The ram of the cylinder is connected to a slide carrying a lipped, channel-section, guide member *L*, and, when air is supplied to the cylinder, the member *L* is moved in a direction parallel to the spindle axis. On the further side and at the left-hand end of the channel member there is a projection with a reduced diameter portion of such a size that it will enter the bores of the blanks in the magazine. This projection has spring fingers whereby the bore is gripped. Another air cylinder, *M*, on the end-working tool drum, moves a slide towards and away from the component at the loading position. This slide has a projection *N*, similar to that on the channel member, and also equipped with spring fingers, which is aligned with the spindle axis at the loading position. When air is supplied to the rear of the piston in the cylinder *M*, the projection *N* is carried forward until it enters the bore of the completed component. At this point in the cycle, the spindle at the loading position has been stopped and the jaws are open. After insertion of the projection *N*, the direction of the air supply to the cylinder *M* is reversed so that the completed component is withdrawn from the chuck and is carried back to a position which is opposite the end of the groove in the member *L*. Just before this sequence of movements has been completed, air is supplied to the rear of the piston in the cylinder *K*, causing it to advance the slide until the projection on the further side of the

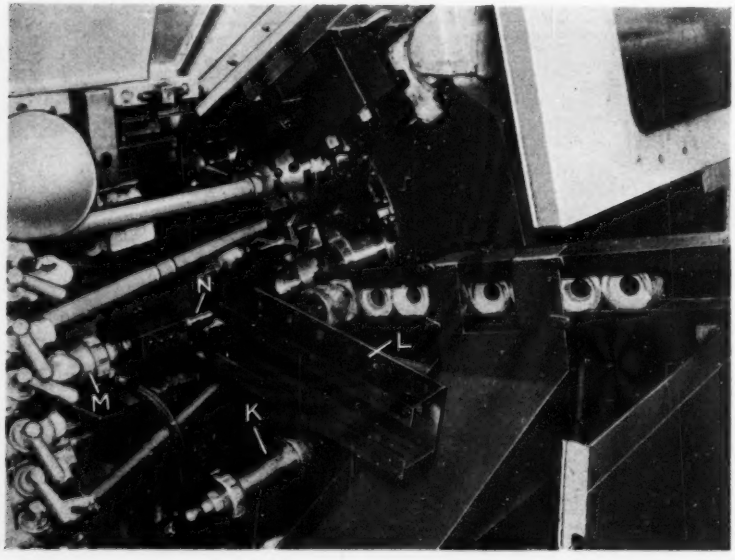


Fig. 12. Close-up View of the B.S.A.-Acme-Gridley 6-spindle Machine for Preliminary Operations on the Clutch Hub Showing the Automatic Loading and Unloading Mechanism

channel member enters the bore of the next blank in the magazine, which is also of U-section, with lips to retain the blanks.

Air supply to the cylinder *K* is now reversed, and the member *L* is retracted, together with the fresh blank, which is withdrawn through part of the magazine opening not fitted with lips, the remaining blanks in the magazine being then free to roll forward under gravity. The cross-slide on which the channel member *L* is mounted now starts to move inwards, carrying the new blank on the projection into a position in line with the open chuck. As the slide moves inwards, the open end of the channel member *L* engages the finished blank on the projection *N*. At this stage, air is again supplied to the rear of the piston in the cylinder *K*, so that the new blank is carried forward into the chuck, the jaws of which are then closed to grip it. As the member *L* moves forward, the finished blank is stripped from the projection *N*, by the lips of the channel and it rolls down on to the chute beneath. Finally, the direction of the air supply to the cylinder *K* is reversed to withdraw the channel member, in readiness for the return movement of the machine cross-slide at the end of the cycle.

A Weatherley Oilgear Cyclematic broaching machine is next employed to produce the internal splines in two hub bores at a time. There are 17 splines of approximately 14·5 D.P., with a pressure angle of 30 deg. and a depth of 0·074 in. A view of the machine, with two broached components in the positions to which they are delivered for unloading, is given in Fig. 13. For loading, the broaches, which are suspended from the upper holder, are automatically raised above the position shown and a blank is then placed against positioning pins on each of the fixtures on the table. When two widely-separated push-buttons at the front of the machine are depressed, the broach-holder, which is connected to the ram of a vertical hydraulic cylinder is lowered, and the ends of the broaches pass through the bores of the blanks and enter clamping jaws on the bed. These jaws are automatically closed to hold the broaches, and the table is then moved upwards, carrying the blanks past the teeth of the stationary broaches so that the splines are cut. When all the broach teeth have been cleared, the upper holder is retracted so that the blanks can be raised above the ends of the broaches. In this position, a roller on a lever which is pinned to a cross-bar carried in brackets at the rear of the table comes into contact with a stop. Further slight upward movement of the table causes the cross-bar to turn, and other levers secured to the bar then advance a thrust-plate *P*, which moves in guide-ways at each side,

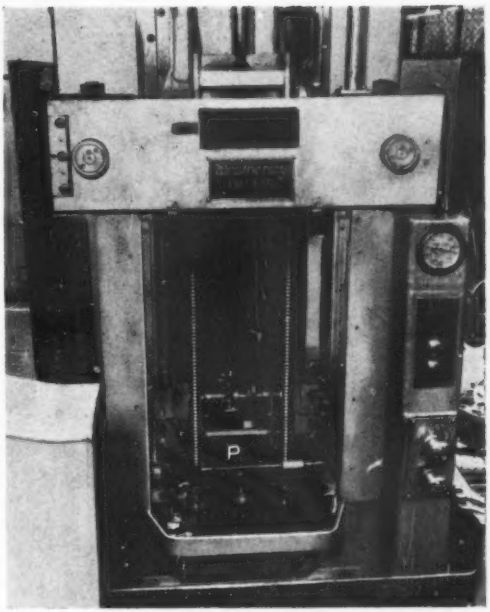


Fig. 13. This Weatherley Oilgear Cyclematic Machine is Employed for Broaching 17 Internal Splines in the Bores of Two Clutch Hubs Simultaneously. The Broaches are Stationary while Cutting is in Progress

to push the broached blanks to the position shown, where they are clear of the broaches. The upper broach-holder then descends and clamps the upper ends of the broaches, the table is lowered to the position shown, and the next two blanks are loaded.

Broached blanks are passed to an adjacent 12-ton capacity Hi-ton [Drummond-Asquith (Sales), Ltd.] hydraulic press on which mandrels are pressed into position in the splined bores, in readiness for turning operations between centres, on a Churchill-Redman multi-tool lathe. On this machine the outside diameter is finish-turned, in preparation for cutting the external teeth; the circumferential groove is finished to size, also the boss at one end; the ends of the portion on which the external teeth are to be cut are faced and chamfered; and the boss is faced and chamfered.

AUTOMATIC LOADING OF HOBBING MACHINES

At the next operation, the external teeth are cut on a battery of eight Rigidhobber machines (Churchill Gear Machines, Ltd.), equipped for entirely automatic loading and unloading. A

view of these machines, which are arranged in two lines of four, facing inwards, is given in Fig. 14. Here the Weatherley broaching machine can be seen at the extreme right, the Hi-Ton press in the right foreground, the Churchill-Redman lathe at the left, and the battery of Rigidhobbers beyond. In front of each line of hobbing machines there is a double conveyor belt system extending for the length of the line, two belts, about 3 in. wide, being arranged one above the other. Both belts for each line are driven continuously by motors at the further end, and blanks which are unloaded from the multi-tool lathe are placed on the upper belt, being loaded alternately on the conveyor at each side. The blanks are carried along until they reach one of the conveyor loading stations, a close-up view of which, from the space between the conveyors, is given in Fig. 15. A fence attached to one of the side walls of the conveyor sweeps each blank to the further side, as it travels from left to right in the illustration.

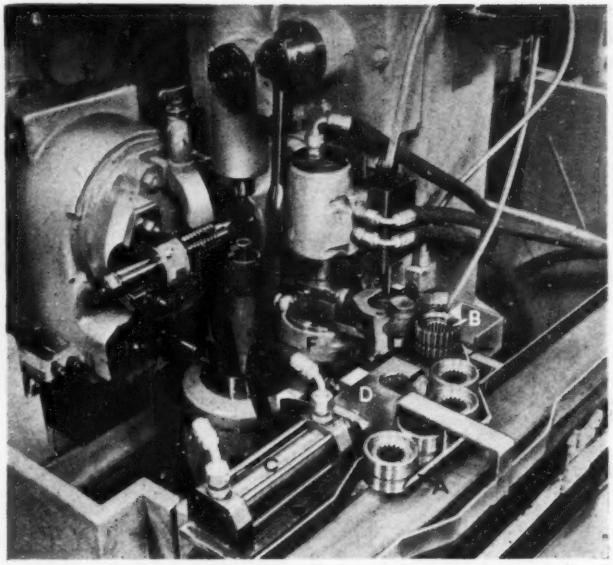


Fig. 15. Close-up View of One of the Rigid-hobber Machines Showing the Automatic Loading and Unloading Arrangements for the Partly-machined Clutch Hubs

At the loading station there is a collector bar *A*, suspended just above the belt, and as each blank approaches it is guided into the space between the collector bar and the side wall of the conveyor. The leading blank is stopped and held in the position shown by a flat spring on the far side, and the collector bar and the corresponding joggle in the conveyor side wall are of such dimensions that up to four blanks can be retained at a time. Any blank which arrives when the maximum number is held at a particular station is deflected to the right by the last blank in the line, and is carried on to the next station, where a similar arrangement is provided. Thus, the loading stations of all the machines are kept full if there is a sufficient supply of blanks. Any blanks which are carried past all the loading

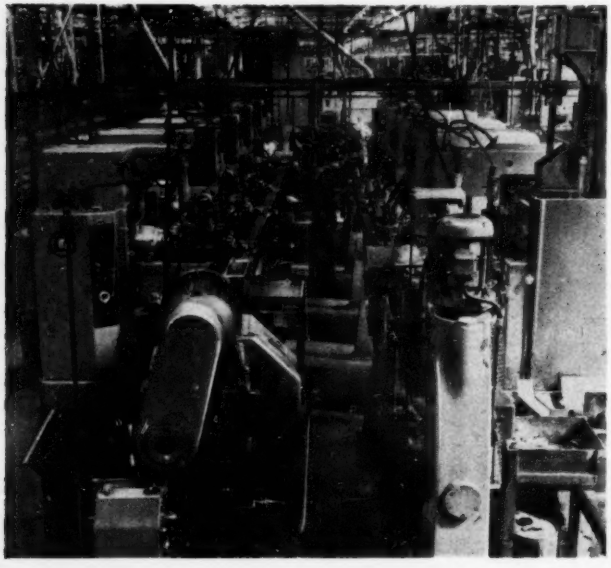


Fig. 14. General View of Part of the Clutch Hub Production Line Showing the Battery of Eight Rigidhobber Machines for Cutting the External Teeth

stations are retained at the end of the belt and are returned by hand.

The mechanism whereby the gears are picked up from the conveyor belt and transferred to the machine spindle was described in MACHINERY, 90/269—1/2/57, in connection with a line of six Rigidhobbers that are employed for cutting three sets of gear teeth on cluster gears for the Victor gearbox. In order to explain the functioning of the complete unit in Fig. 15, however, it will be necessary briefly to describe this mechanism again. At the end of the automatic cycle of the hobbing machine, a finished gear, *B*, is transferred to a flat steel platform at one side of the conveyor belt. Mounted on this platform there is a small hydraulic cylinder *C*, to the ram of which is attached a feed plate *D*, of a thickness such that it will pass beneath the lower rim of the blank as it stands on the boss at one end. At the first stage in the automatic loading cycle, oil is supplied, through a solenoid valve, to the rear of the piston in the cylinder *C*, so that the plate *D* moves forward, until its leading edge makes contact with the boss on the under-side of the finished gear *B*, pushing it off the edge of the support platform, whence it passes down a chute leading to the lower conveyor belt. This lower belt travels in the same direction as the upper belt, and it carries the gear along to the far end of the line, where it is stopped by a baffle.

Behind the leading edge, the plate *D* is cut away to a U-shape, so that a second edge is provided on the side adjacent to the uncut blanks. As the plate advances, this second edge slides beneath the rim of the next blank to be loaded until it comes into contact with the boss and starts to move the blank forward. As the blank moves, it is deflected to the left, into the U-shaped cut-away portion, by an inclined bar *E* on the side of the conveyor. The fresh blank is thus carried into the exact position formerly occupied by the finished gear, ready to be picked up and loaded into the machine.

The loading jaws, which are seen open in Fig. 15, have projections to engage the circumferential groove in the blank, and are closed by a small hydraulic cylinder in the arm whereby they are carried. Then, an overhead cylinder raises the arm so that the blank is held at such a level that it will clear the top of the machine spindle. At the lower end, the loading arm is connected to a sleeve provided with an axial vane which projects into an annular space in the housing *F*, and when oil is supplied to one side of this vane, the arm is swung round until the movement is arrested by a stop. In this position, the fresh blank is directly above the machine spindle, and the two cylinders are successively actuated to lower the blank into place and to withdraw the clamping jaws. Next, the tailstock descends to clamp the work, and the hobbing cycle begins. After hobbing has been completed, the tailstock is retracted, the jaws grip and raise the work, as shown in the view from the opposite side in Fig. 16. Then, they swing round, and deposit the finished gear on the platform, as seen in Fig. 15. The complete unloading and loading cycle occupies 10 sec., and each movement is initiated by the operation of a limit switch at the completion of the previous movement, whereby a hydraulic solenoid valve is opened or closed.

As reported in MACHINERY, 83/767—16/10/53, some of the experimental work that resulted in the design of the latest Rigid-

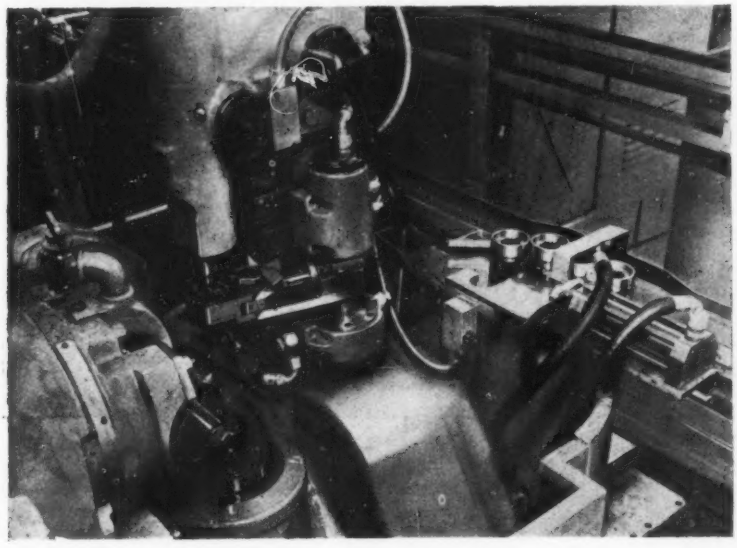


Fig. 16. In this View of the Rigidhobber, a Completed Component is Being Lifted from the Arbor by the Hydraulically-actuated Fingers, for Transfer to the Conveyor Belt

hobber machine was carried out on modified Churchill-Cleveland Rigid machines at the works of Vauxhall Motors, Ltd., and most of the gear-cutting machines now in operation there are run at the speeds established during this investigation. The gear cut with the set-up shown in Fig. 16, has 24 teeth of 10·16 D.P., with a pressure angle of 25 deg., a depth of 0·1199 in., and a length of 1·58 in. A single-start hob of 3 in. diameter, with 20 straight gashes, is driven by a 5-h.p. motor at a speed of 310 r.p.m., so that the surface speed is about 246 ft. per min. The climb-hobbing technique is employed, with the machine operating on the O-cycle, and the hob starts at the bottom, and is fed upwards at the rate of 0·060 in. per rev. of the work.

Each gear is completed in 5 min. which includes the loading and unloading time. The hob-shift mechanism on the machine is arranged to give the full movement of the 3-in. long hob in a period of about 5 hours, so that a life of approximately 60 gears per regrind is obtained. When regrinding the hobs, about 0·006 in. of material is normally removed from the teeth, and each hob can be reground about 50 times, so that an output of the order of 3,000 gears per hob is obtained.

At the further end of the row of machines seen in Fig. 14, there is a battery of Maxicut No. 2A gear shapers, arranged transversely across the shop, three of which are employed for the next operation on the clutch hub, the remainder being concerned with the mainshaft. On the Maxicut machines, which are manually loaded, one side of each tooth at the end adjacent to the reverse idler gear is relieved to a depth of 0·008/0·010 in. for a distance of 0·805 in., as indicated in the drawing Fig. 11, in a cycle time of approximately 2 min. 20 sec. After this operation, the teeth of the gears are de-burred by hand and with the aid of a wire-brushing machine.

The gears then pass to the Lapointe S.R.V. vertical broaching machine, shown in the close-up view in Fig. 17, on which the three slots for the sliding keys, mentioned earlier, are cut. Each gear is located on a plain cylindrical spigot, and is angularly positioned by a profiled pin which engages one of the external tooth spaces. Clamping is effected hydraulically, by means of the massive lever, seen in the withdrawn position, when the two cycle-start buttons are pressed simultaneously, and the fixture is then fed forward to a stop, ready for the broaching operation. Three separate broaches are carried in the vertical slide, each designed to cut one complete slot and to relieve the sides of the adjoining teeth to a depth of 0·008/0·013 in. over their entire length. Each broach is 6 ft. long, and the operation is carried out at a speed of 12 ft. per min. with Ilobroach No. 9 (C.C. Wakefield & Co., Ltd.) broaching oil.

Broached gears are de-burred and placed in baskets on a continuously-moving overhead conveyor, whereby they are carried through a large washing machine which handles all the components produced in the section. On emerging from the washer, the gears are transferred to the machine shown in Fig. 18, on which they are selectively hardened in the positions indicated in Fig. 11. The Birlec induction machine provides for hardening at the three positions in succession, automatically. Each component is loaded on the heat-insulated upper end of a vertically-moving mandrel, which is raised and lowered by a plate cam in the base, driven through reduction gears by a small motor. This cam makes one revolution during the machine cycle, and it is designed so that the mandrel is caused to dwell at each of three positions. Within the enlarged upper end of the bore in which this mandrel travels, there is an induction heating coil, and the bore is lined with heat-resistant insulating material to guide the component as it moves up and down.

At each of the dwell positions of the mandrel, a switch is operated to supply current, at 350,000 cycles per sec., from the Phillips 25-kW. high-frequency generator at the extreme left in Fig. 18, to the coil for a pre-set period. At the end of

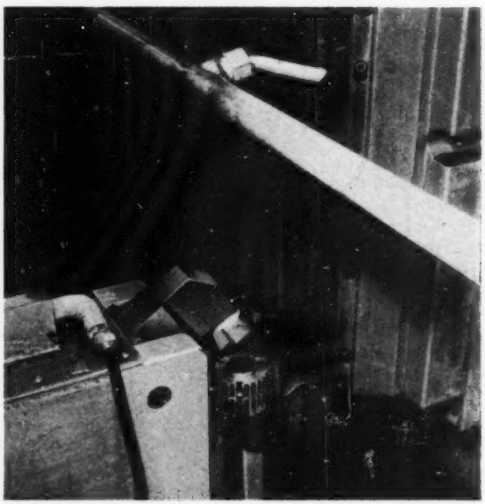


Fig. 17. On this Lapointe S.R.V. Vertical Machine Three Approximately Square-section Slots are Broached and the Gear Teeth Adjacent to Each Slot are Relieved

Fig. 18. The Teeth of the Clutch Hub are Selectively Hardened on this 25-kW. Birlec Induction - heating Machine, which Operates on an Entirely Automatic Cycle

this period, the current is automatically switched off and a valve is opened to allow quenching water to flow on to the heated portions of the gear. After the component has been loaded, the automatic cycle is initiated by press-button, and the gear is then carried down on the mandrel, until the band near the centre, which is to be hardened, is correctly positioned in the coil. The mandrel now dwells in this position while the current flows in the coil for 2·6 sec. to heat the teeth, and as soon as the current is switched off, the quenching water is turned on and allowed to flow for 10 sec. When the component has been quenched, the cam lowers the mandrel further, so that the upper end is positioned in the heating coil and the current is switched on for 1·6 sec. followed by quenching for 5 sec. Similar heating and quenching periods are employed for the lower end of the gear when it is raised into the coil, and, finally, the gear is returned to the upper position for unloading.

Next, the components are heat-treated in a vertical pit type tempering furnace, and for this stage they are loaded into jigs, each of which holds 56. Finally, the machining operations are completed by grinding the tips of the external teeth to a diameter of 2·464/2·4635 in. on a Precimax (John Lund, Ltd.), machine with the components mounted on mandrels. Inspection is carried out with Parkson and Orcutt machines, and there is also a percentage check for hardness.

AUTOMATIC RETAINING-RING CLINCHING MACHINE

A pressed steel retaining ring, which serves to prevent excessive movement of the three keys in the longitudinal slots in the clutch hub, is next pressed over the boss at one end and clinched in position at three places. The ring has three projections, which enter the slots in the hub, and, at the clinching operation, the sides of the ring are pushed inwards into the undercut in the boss. A view of the special machine for this operation, supplied to the design of Vauxhall Motors, Ltd., by Butro Jig & Engineering Co., Ltd., is given in Fig. 19, and it takes the form of a press with a vertical air cylinder in the box-shaped cast head. In the sectional view of the press in Fig. 20, this cylinder is indicated at G. Between the sealing

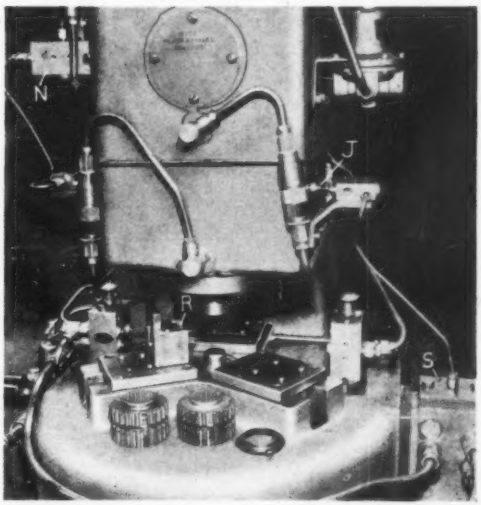


Fig. 19. A Retaining Ring with Three Projections which Enter the Slots in the Sides of the Hub to Restrict the Movement of the Synchomesh Keys is Pressed On and Clinched in Place on this Special Press which has a Pneumatic Ram

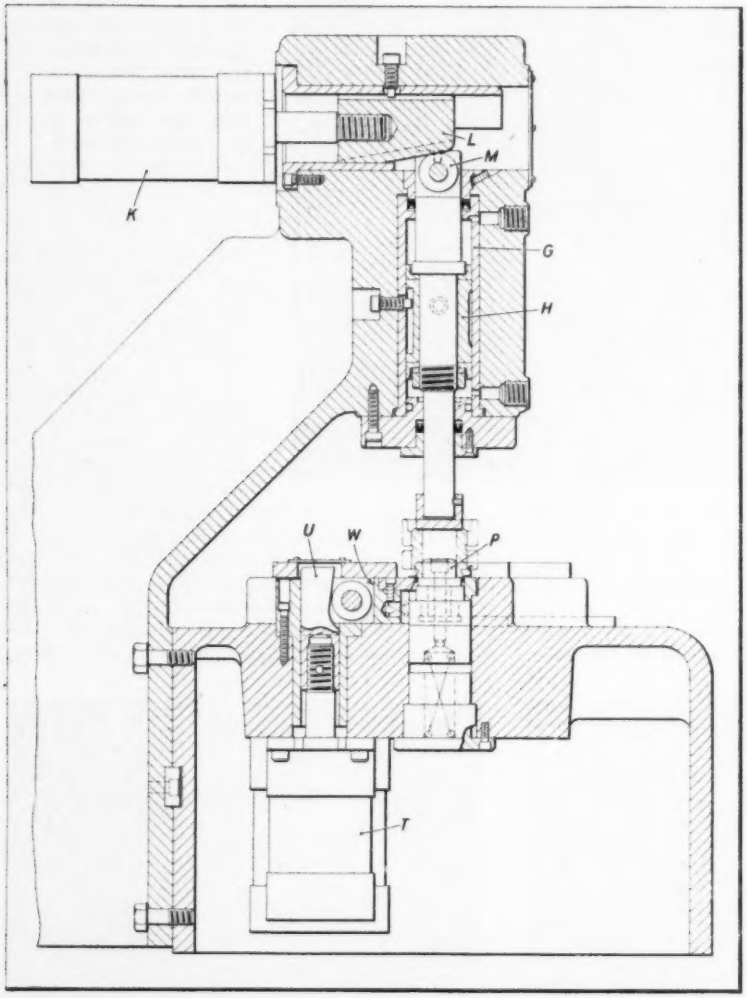


Fig. 20. The Arrangement of the Clinching Press for the Clutch Hub Retaining Ring. After the Upper Mandrel has Pushed the Gear into the Ring and Clamped it, Side Punches Move in to Clinch the Projections

rings for the piston in the cylinder, there is a sleeve *H*, which is pinned to the ram. The latter is prevented from turning by a pin on the main casting, which projects into the cylinder and enters a longitudinal groove in the sleeve.

On the outside, the sleeve is machined to form cam surfaces at the upper end, in positions at 90 deg. to the pin on each side, and as the ram moves vertically, these cams act on horizontal plungers housed in the head casting. The outer end of one of these plungers is indicated at *J* in Fig. 19, and the other plunger, on the opposite side of the head, is located at a slightly higher level. Thus, as the ram moves down, the plungers are thrust outwards in succession, against the pressure of coil springs, and they operate pilot valves carried on brackets on each side of the press head, to initiate further stages in the automatic machine cycle. At the rear of the press head, there is a horizontal air cylinder *K*, Fig. 20, the ram of which carries a wedge *L*. The upper end of the vertical cylinder ram projects into the space occupied by the wedge, and has a slot in which is pinned a roller *M*. When the ram has been moved down to the position shown, the plunger on the left-hand side of the head has been pushed out by the sleeve *H*, and has operated the pilot valve on that side, which, in turn, has operated the larger valve *N*, Fig. 19, to admit air to the rear of the piston in the cylinder *K*, Fig. 20, so that the wedge *L* has been moved forward.

The clutch hub, shown in chain-dotted outline in Fig. 20, is loaded, spigot-end downwards, on a shouldered mandrel *P*, which is held in the position indicated by a coil spring. Before it is loaded, a retaining ring, as shown on the front of the machine in Fig. 19, is fitted over the hub spigot, with its projections engaged in the hub slots. The angular position of the component is determined with the aid of a retractable spring-loaded finger in a housing *R*, which engages one of the hub

slots. When the wedge *L*, Fig. 20, is advanced, it pushes down the vertical ram, so that the clutch hub also is moved down until its lower step face, adjacent to the teeth, rests on a fixed annular insert surrounding the mandrel *P*. At the completion of this downward movement, the plunger *J*, Fig. 19, is moved outwards, in turn, to operate the associated pilot valve, which controls the large valve *S*. This valve supplies air to three equally-spaced cylinders, within the press base, one of which is seen at *T* in Fig. 20.

A wedge *U*, attached to the ram of this cylinder, acts on a roller on a crimping slide *W*, housed in guide-ways on top of the bed casting, when air is thus supplied to the ram side of the piston. At its inner end, the slide *W* carries a crimping tool, with a wedge-shaped end, which presses the metal of the cylindrical portion of the retaining ring into the under-cut of the hub spigot to secure the ring in position. The press is controlled by means of a hand-operated valve on top of the bed casting at each side, and these valves must be depressed together, and held down. When the valves are released at the end of the machine cycle, which occupies only a few seconds, the air supply is cut off from both the pilot valves, with the result that the plungers of the large valves *N* and *S*, Fig. 19, are returned by springs to their original positions.

Reversal of the air supply to the horizontal cylinder results in retraction of the wedge *L*, Fig. 20, and since the air pressure is now acting on the under-side of the piston in each of the vertical cylinders *T*, the wedge cams *U* are raised, and the crimping slides can move outwards under the action of their return springs. With the retraction of the wedge *L*, air pressure acting on the under-side of the piston in the cylinder *G* can raise the vertical ram, so that the component can be unloaded.

ROLLING OIL GROOVES IN MAINSHAFTS

At one of the more interesting operations carried out on the mainshaft for the Victor Gearbox, oil grooves are rolled in positions which are occupied by the bores of gears in the final assembly. The mainshaft is machined from a steel forging which is first faced, centred, and drilled on a Standard-Modern duplex machine, and then copy turned at the front end (in the car) in two operations on +GF+ (Vaughan Associates, Ltd.), and Churchill-Redman lathes. Forgings on which these operations have been completed are seen in the foreground in Fig. 21, which shows a close-up of the Michigan Roto-Flo [Ex-Cell-O Corporation (Machine Tools), Ltd.] spline-rolling machine for forming the oil grooves. There are four portions of 1·398/1·402 in. diameter, in each of which 33 oil grooves are required, and each groove is approximately ½ in. long. The grooves are 0·039/0·047 in. wide at the top, and, in section, each has curved sides of 0·08-in. radius, struck from a line radial to the shaft axis. At the bottom of the groove, the curved sides are joined by a radius of 0·01 in. The Michigan machine was described in MACHINERY, 85/919—29/10/54, and it has a massive frame, of C-shape, incorporating two slides on which rack-type forming tools are carried. One of the tools for the oil-grooving operation is indicated at *A* in Fig. 21, and there is a matching tool secured to the under-

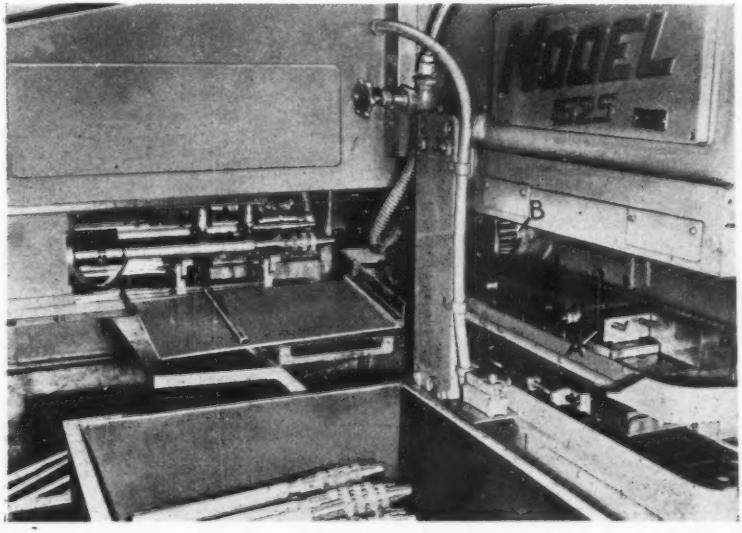


Fig. 21. With this Set-up on a Michigan Roto-Flo Spline-rolling Machine, Four Rows of Oil Grooves are Rolled into Bearing Surfaces on the Gearbox Main-shaft in a Cycle Time of 8 sec.

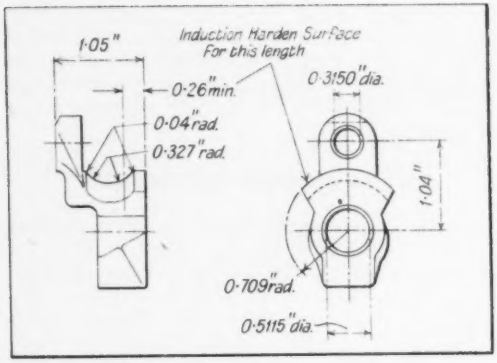


Fig. 22. Views of the Gearbox Striking Lever. The Portion which is Induction Hardened is Indicated

side of the upper slide. Each slide carries a heavy-duty master rack, the teeth of which are engaged by a pinion *B*. It is thus ensured that the movements of the two tools are synchronized.

The loading arrangements for the machine are entirely automatic after the partly-machined shafts have been placed in a magazine on the further side of the horizontal member at the upper left in Fig. 21. This magazine has a sloping surface with ridges, down which the shafts roll, and a hydraulic cylinder is connected to fingers which feed the next shaft into the fixture for the rolling operation. At the same time, the previously-completed shaft is pushed into a chute, whence it is delivered to the container in the foreground. The fresh shaft is held down on V-locations by spring pads, and the fixture is so arranged that it can be moved bodily sideways by means of a hydraulic cylinder, to carry the shaft up to a stop within the opening in the machine frame. The shaft is pressed against the stop by a spring-loaded rotating pad at the left-hand end, so that it is positively located, and the upper and lower tool slides are then actuated to roll the grooves. For this operation the cycle time is approximately 8 sec., and a special oil is employed to lubricate and cool the work and tools.

After the grooves have been rolled, the shafts are turned and formed on a Maximinor lathe, and the grooved portions are then ground to a diameter of 1·4734/1·4739 in. with a formed wheel. Subsequent operations provide for cutting three sets of gear teeth, copy-turning the remainder of the shaft, forming three circlip grooves, carburizing and straightening, and hardening and tempering. Cylindrical grinding of the more important diameters is then carried out, and, finally, the surfaces in which the oil grooves were rolled are copper-plated to a thickness of 0·0004/0·0005 in. to ensure trouble-free running-in during the early life of the car.

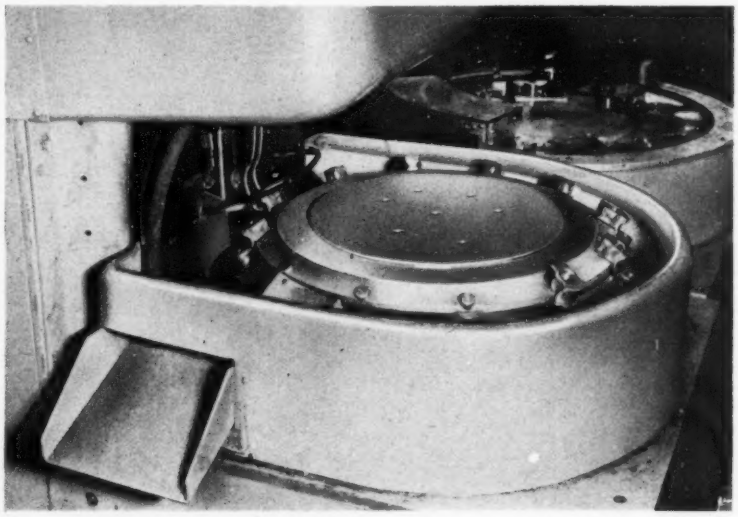


Fig. 23. One of the Fixture Tables on the Wild-Barfield Machine for Induction-hardening the Surface of the Striking Lever. The Levers are Loaded Manually and Unloaded Automatically in Front of the Chute at the Left

INDUCTION-HARDENING MACHINE FOR STRIKING LEVERS AND FORKS

Striking levers and forks for the Victor gearbox are manufactured in the same section of the factory as the components so far discussed, and hardening operations on these components are carried out on a duplex-type Wild-Barfield high-frequency induction hardening machine. Views of the striking lever, which is machined from a forging, are

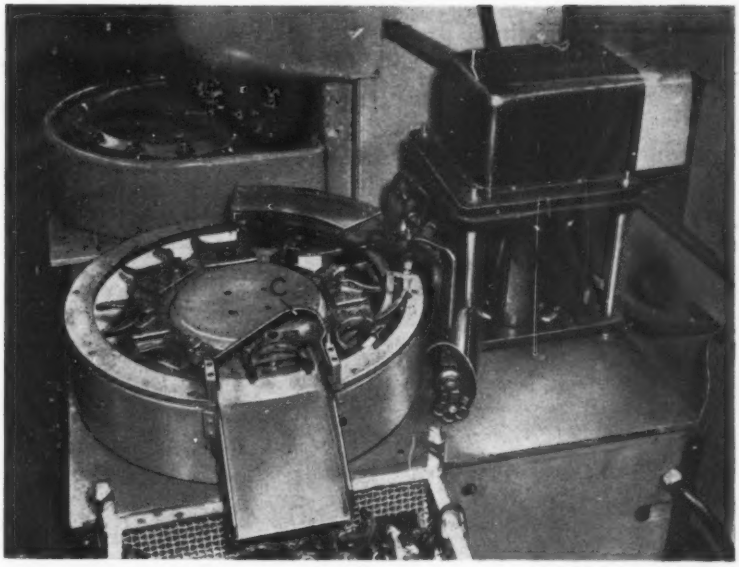


Fig. 24. On the Other Fixture Table of the Wild-Barfield Machine, Two Types of Gearbox Striking Forks are Accommodated for Induction Hardening of the Pad Surfaces. Provision is Again Made for Automatic Unloading

shown in Fig. 22. Operations on the lever, prior to hardening, comprise drilling, reaming and chamfering the large and small holes, milling to length, milling the 0·709- and the 0·327-in. radii simultaneously with a form cutter on a cam-controlled machine, and milling the sides to the form and dimensions shown. The levers then pass to the Wild-Barfield machine, which is of 15-kW. capacity and is supplied with current at a frequency of 250,000 cycles per sec. A close-up of the fixture table provided for the levers on one side of the machine is given in Fig. 23, where the other fixture table, for the striking forks, may be seen in the background. Loading is carried out at the front of the machine, which is on the right, and the levers are placed over pegs near the edge of the table. These pegs are so mounted that they can be retracted downwards by a cam beneath the table at the position opposite the chute in the left foreground, and the levers are thus released and fall down a chute into a container.

The table is indexed in an anti-clockwise direction by means of an air cylinder. On the lower end of the table support-spindle there is a disc with a number of slots in its periphery, corresponding to the positions of the lever-retaining pegs in the table. A spring-loaded pawl on the ram engages these slots in succession, when air is supplied to the cylinder for the indexing operation, and the table is positively located by a detent pin which enters another slot. The water-cooled coil, through which the high-frequency current passes, is so arranged that it almost completely surrounds the area of the component which is to be hardened. This area is indicated in Fig. 22. When the table is to be indexed, the coil is raised by an air cylinder to a setting clear of the component which has just been treated. All the movements of the machine are synchronized and automatically controlled by solenoid valves and limit switches so that the operator is only required to load the table and remove the boxes of completed parts. The heating time for the lever is 10 sec., and it is automatically quenched by a water spray from each side. A hardness value of 50 to 60 Rockwell C is obtained with this equipment.

Striking forks for the Victor gearbox are of two slightly different designs, one with the mounting boss centrally located in relation to the forks, and the other with the boss offset. A similar series of operations is employed for machining forks of both patterns, and, first, the outer faces of the boss are broached, and the mounting hole is drilled, reamed, and chamfered. Then, the sides and inner surfaces of the finger pads are broached at two successive operations, and a $\frac{3}{16}$-in. diameter hole is drilled through the boss for a locking pin. Subsequently, the components are de-burred, washed, and passed to the Wild-Barfield machine on which the pad faces are hardened.

The second fixture table on the machine is shown in the close-up view, Fig. 24, and it will accommodate each type of fork at alternate positions. The table is driven continuously at a slow speed by a small motor in the base, through a reduction gearbox, and the parts are loaded at the front of the machine, on the left. Each fork is located, by the hole in the mounting boss, on a pin projecting from each rec-

tangular platform, of which there are eight. The platforms are mounted on the tops of large-diameter, hollow plungers accommodated in holes near the table edge, and each has two small steel blocks for locating the fork from the outside surfaces. These blocks also ensure that the offset and central-boss forks are loaded at the correct stations.

The table rotates in a clockwise direction, and, as the forks are carried round, they pass through a heater coil of quadrant form on the far side of the table. Passage through this coil occupies 15 sec. and when the forks leave, the pads are at bright red heat. Continued rotation of the table carries the forks through a quenching spray of equal parts of water and soluble oil supplied by way of a manifold pipe which is also of quadrant shape.

Each fork then passes beneath the formed loop *C*, which is made from strip steel, and when it reaches the position shown, the lower end of the plunger carrying the platform comes into contact with a cam surface beneath the table. The platform is thus raised, and the fork is lifted to a height at which it will be swept off by one side of the loop *C*. Since the locating pin for the hole in the boss is fixed, the component is lifted clear as the platform is raised. The current setting, table speed, and quenching oil are selected to ensure a hardness of 48 to 50 Rockwell C on the pad surface. The equipment seen on the right in Fig. 24 is a high-frequency transformer from which current is supplied to the heating coil. A similar unit is provided for the other fixture table.

Machining and other operations on the stub axles for the Vauxhall Victor car will be discussed in a further article to be published shortly in MACHINERY.

Indicating and Recording Ultrasonic Thickness Gauge

The type R ultrasonic Vidigage, shown in the figure, has been introduced by Branson Instruments, Inc., U.S.A., for indicating and recording thickness measurements and detecting flaws. This unit will measure thicknesses of metals, glass, and plastics ranging from 0·005 to 2·5 in., and it is stated that readings of a high degree of accuracy are obtained. A transducer is applied to one surface of the work, and the resonant frequency is then detected and converted directly into a thickness indication.

The Type R Ultrasonic Vidigauge which Indicates and Records Thickness Variations

The strip chart recorder clearly shows thickness changes which are barely visible on the screen of the cathode ray tube. A recordindg pen is actuated by an amplified signal, proportional to the difference between the work thickness and a standard to which the equipment has been set. As a result, highly magnified record of thickness variations is provided.

A gating and alarm circuit is arranged to trip a relay when predetermined thickness limits are reached, and this relay can be employed to energize an audible or visible signal, a marking device or a sorting attachment. Extra circuits can be added, if required, to enable work to be segregated into a number of thickness groups.

In one instance, this gauge was employed for checking seamless steel tubing with a nominal wall thickness of 0·074 in. The tube was rotated continuously at 35 r.p.m., and the transducer was traversed at the rate of about 0·5 in. per rev.

The chassis holding the cathode ray tube and associated circuits can be removed from the cabinet and installed in a carrying case if portability is required. In addition to the standard equipment, circular charts, multi-pen recorders, and other special recording apparatus can be employed.

The Dimensioning and Quality Control of Involute Splines

Design and Inspection Methods used in the U.S.A.*

By ALBERT S. BEAM† and LEON N. DeVOS†

In recent years, multi-tooth involute splines have been increasingly adopted in the engineering industry, and their introduction has resulted in a number of problems connected with the dimensional control of tooth and space widths.

A spline provides for locations on a number of matching tooth surfaces, and this basic requirement represents a contradiction of the rule that multiple locating surfaces should be avoided.

To overcome this problem of location, it is necessary to adopt a system of dimensioning which is peculiar to splines, and the idea of "effective" and "actual" width dimensions, which is explained in this article, was first proposed by the Vinco Corporation, Detroit, Michigan, U.S.A., in their 1945 catalogue. Subsequently, this system of dimensional control was adopted throughout the U.S.A. as a result of the 1950 revision of the American Standard B5.15 for Involute Splines.

It will be appreciated that the fit between mating splined members is not sufficiently defined by the space width of the female member and the tooth thickness of the male member. Spacing, profile, out-of-roundness, and lead errors also effect the fit. To illustrate this point, reference may be made to Fig. 1. Two splined members are here shown, and it is assumed that the female spline has pitch and profile errors, as shown at *A* (there are no out-of-roundness and lead errors), whereas the male spline is of theoretically-correct form. At this stage, the width of the spaces in the female member and the thickness of the teeth on the male member are known as the "actual" space width and the "actual" tooth thickness, respectively.

If an attempt is made to assemble these two parts, interference will occur as indicated at *B*. To allow the male spline to enter the female spline in any desired position, it is necessary to reduce each of the teeth on the male member by the amount of interference which is shown at *B*. Assembly of the two parts can then take place, without interference, as indicated at *C*. In effect, therefore, the "actual" space width of the female member, minus the amount of interference already mentioned, represents the space width which is available to receive the tooth on the male member, and this dimension is known as the "effective" space width of the female spline. The "effective" tooth thickness of the male member is the "actual"

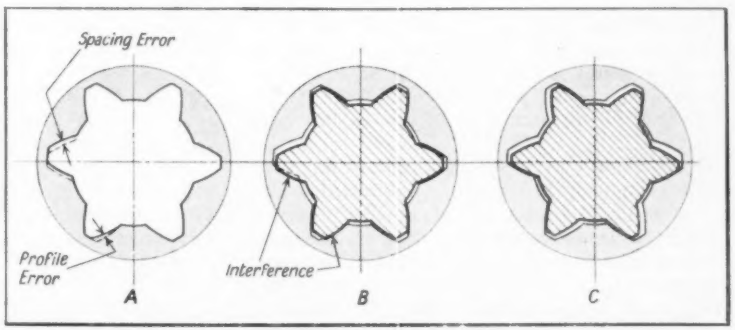


Fig. 1. (*A*) Diagram of an Internal Involute Spline with Spacing and Profile Errors (Out-of-roundness and Lead Errors are Not Shown). (*B*) If a Theoretically-correct External Spline is Inserted in the Internal Spline shown at *A*, Interference will Occur Owing to the Errors in the Latter. (*C*) The Tooth Thickness of the External Spline has been Reduced by the Amount of the Interference Shown at (*B*). This Reduced Thickness Represents the "Effective" Space Width of the Female Member

* This article contains excerpts from papers presented to the Detroit Chapter of the A.S.T.E. in June, 1958.

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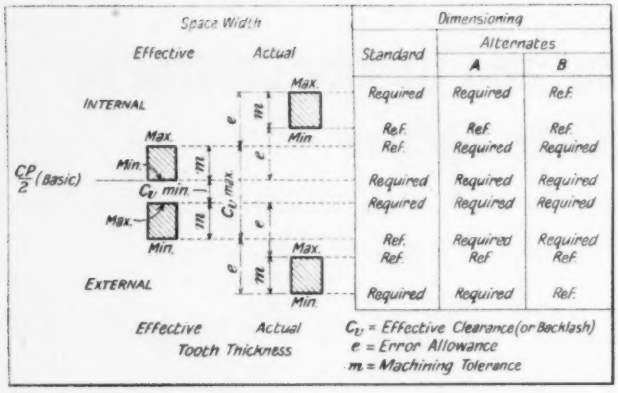


Fig. 2. Chart Showing the Specifications for Tooth-thickness and Space-width for Three Different Control Systems. At the Left are Indicated the Relationships Between the Effective and Actual Space-widths and Tooth-thicknesses for a Pair of Splined Members Designed to Assemble as a Sliding Fit

thickness plus the amount of interference already mentioned. As can be seen at the left of the chart shown in Fig. 2, for a "standard" fit, the minimum effective space width of the female member is never less than the maximum effective tooth thickness of the male member, and the difference between these two dimensions represents the minimum effective clearance (or backlash) present in the assembled parts. This clearance, in turn, establishes the type of fit obtained with the mating parts.

Actual tooth thickness on the male member is the circular thickness of a single tooth measured on the pitch circle. Actual space width and actual tooth thickness are checked by means of pin measurements, or by gauges designed to contact single spaces or teeth which are diametrically opposite.

The difference between the effective and actual dimensions represents the accumulated effect of the spline errors, this difference being called the effective error, and the amount of effective error which can be permitted is known as the error allowance.

In the chart Fig. 2, the specifications for space width and tooth thickness are represented diagrammatically. At the left of the figure, a bar chart illustrates the relationship between the effective and actual space width and tooth thickness dimensions for a pair of splined members which are required to assemble as a sliding fit. The actual space width and the actual tooth thickness are allowed to vary within given machining tolerances, and the effective dimensions are controlled in a similar manner. Consequently, there are four limiting dimensions for each member, and these dimensions are derived as follows:

The basic dimension is the minimum effective space width, which, in turn, is equal to half the circular pitch. This datum requires that the internal spline should be accepted by a basic "go" composite plug gauge. From this datum, the maximum effective tooth thickness can be established, as this dimension is controlled by the desired minimum effective clearance (or backlash). To determine the maximum effective space width and the minimum effective tooth thickness, the total permissible fit variation is distributed between the internal and external splines, according to manufacturing requirements. Limiting dimensions for the actual space width are determined by adding a suitable error allowance to the effective space width; similarly, maximum and minimum actual tooth thickness are calculated by subtracting a suitable error allowance from the effective tooth thickness dimensions. These error allowances are governed by a consideration of the duty for which the splined members are intended, and the accuracy of the manufacturing methods which are being employed.

Minimum and maximum effective clearance (or backlash), which represent the limits for any particular fit, are shown in the chart Fig. 2, as the differences between the effective dimensions of the internal and external splines. The spread between actual space width and actual tooth thickness constitutes the nominal clearance, but this does not define the fit because it makes no allowance for the effect of spline errors.

The introduction of effective and actual dimensions not only gives the designer a discriminating means of expression, but also the responsibility for the correct selection of specifications. In practice, a complete set of all limiting dimensions, shown in the chart, is rarely required. The combination of limiting dimensions necessary for manufacturing a pair of splined members is known as the control system, and the chart shows three such systems, namely, "standard," "A," and "B." Splines which are required to transmit power utilize systems "standard" and "A," whereas for splines which transmit motion only, system "B" is used, also for press fits.

Various dimensions in each system are desig-

nated either "required" or "reference." For instance, it will be noted that the minimum actual space width and the maximum actual tooth thickness are each indicated as reference dimensions in all three control systems, as these two dimensions do not establish the acceptance or rejection of parts. If, for example, the actual space width of the female member is less than the specified minimum, without causing the effective space width to be undersize, or if the actual tooth thickness is greater than the specified maximum without causing the effective tooth thickness to be oversize, then the effective errors would be less than the permissible error allowance. In this case, the quality of the splined members is better than was anticipated, because the full error allowance which was permitted has not been utilized.

Provided the minimum effective clearance (or backlash) is maintained, under-size actual space width or oversize actual tooth thickness are not only permissible, but desirable. However, these two dimensions may be required for reference purposes, as they allow the machine operator to determine, from pin measurements, or indicator gauge readings, whether or not errors in the machining are within the anticipated limits. These reference dimensions are also used to determine the cause of undersize effective space width or oversize effective tooth thickness, either of which may be due to the relevant "actual" dimension not being within the specified limits.

"STANDARD" AND "A" CONTROL SYSTEMS

The "standard" control system, which is suitable for the majority of applications, requires the extreme effective and actual dimensions to be specified, for instance, the maximum effective tooth thickness and the minimum actual tooth thickness. With this system, the maximum spread of the limits is controlled, this spread being the sum of the machining tolerance and the error allowance, and either of these factors is allowed to increase at the expense of the other. As previously mentioned, an increase in machining tolerance, with a reduction in spline form errors, is permissible, because it is advantageous. Any increase in spline errors would be discovered, eventually, through a rise in the number of parts being rejected, and this would necessitate a closer control of actual space width or tooth thickness. This system would permit of

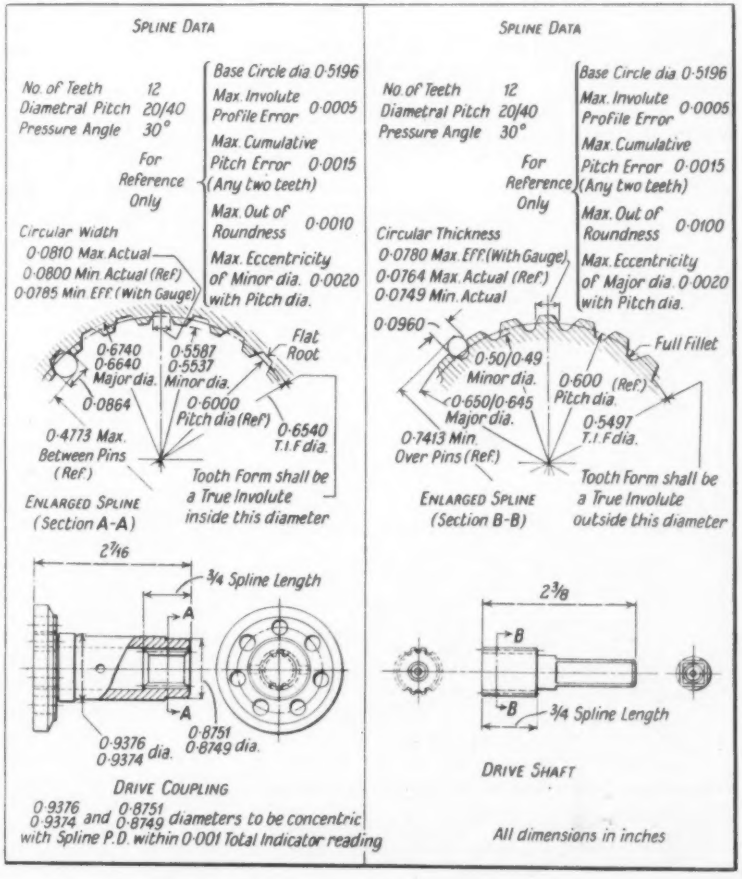


Fig. 3. A Completely-dimensioned Pair of Splined Members Designed to Assemble as a Sliding Fit, for which the "Standard" Control System has been Used. The Splines are of the Flank-fitting Type

machining to the extreme actual size with a very minimum of spline errors, but the maximum effective clearance would approach the maximum nominal clearance, and would cause excessive backlash. Since the extent to which spline errors can be reduced is limited by the nature of the manufacturing processes employed, the increase in backlash never extends to the maximum nominal clearance. In most cases, the probable extent of an increase in backlash will not be great enough to require additional controls. However, when it is essential that the amount of backlash should not exceed the predetermined limits, it is possible to specify a dimension for the maximum effective space width and the minimum effective tooth thickness, as shown in control system "A." The addition of these dimensions will require extra inspection equipment and time.

CONTROL SYSTEM "B"

Control system "B" is designed for those splines which require to be inspected for minimum and maximum looseness only, without regard to the width of single spaces and single teeth. In this system, the effective dimensions only are used as control limits for final inspection, and spline errors are permitted to cause variations of actual sizes, without control. This system is suitable for applications where the amount of contact area between mating splines is of secondary, or no, importance, or, in the case of press fits, where localized interference is sufficient to meet operating requirements. This system is also used when spline form errors are controlled by standards room inspection.

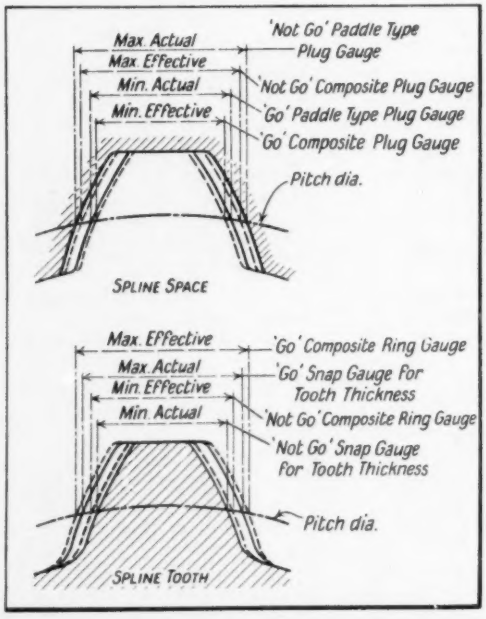


Fig. 4. Diagrammatic Views of a Tooth and a Space Showing the Basic Effective and Actual Dimensions

The selection of a suitable control system solves the problem of space width and tooth thickness specifications. In addition to the tooth thickness and space width, all other spline elements should be clearly defined, as shown in Fig. 3, which illustrates a completely-dimensioned pair of splined components. A sliding fit is required for the splined portions of these components, and the "standard" control system has been employed. Most designers are familiar with the specification of major and minor diameters and limits for these dimensions, but it should be pointed out that close limits are not required for these diameters if the fit occurs at the sides of the teeth.

The specification of a true involute form (T.I.F.) diameter should not be omitted, since it allows the process engineer and gauge designer to establish the depth of the required tooth profile without reference to the mating part. Usually, this dimension exceeds slightly the depth of engagement with the mating part. This extension of true form depth is called the true form clearance, and allows for the looseness between mating splines and for any eccentricities of the major and minor diameters.

It is important that the note "for reference only" should be placed against those dimensions which, in the designer's judgment, do not require individual inspection. In the case of the "standard" control system, where the sum of the effective error and the machining tolerance is held within the spread of the maximum actual and minimum effective space width, or maximum effective and minimum actual tooth thickness, all spline errors are marked as reference data. Loss of time entailed in a comprehensive inspection of all tooth elements is thus avoided. If paddle gauges or snap gauges are intended to be used for checking maximum actual space width and minimum actual tooth thickness, the relevant pin measurements are marked "reference," because they will be required only if the gauges are not available.

The selection and dimensioning of splines is facilitated by the use of existing standards, such as the American Standards B5.15-1957 for Involute Splines, and B5.26-1947 for Involute Serrations. The American Standard B5.15 recommends two types of basic fit, the side fit, and the major-diameter fit. The latter has the advantages that

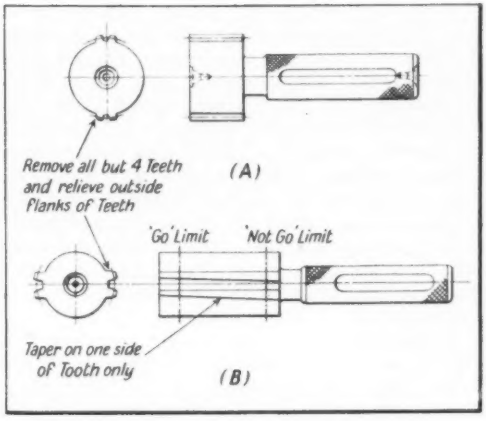


Fig. 5. Straight-tooth and Tapered-tooth Paddle-type Plug Gauges Used for Checking Internally-splined Parts. The Gauge shown at *B* has Scribed Lines to Indicate the Extremes of Depth of Engagement

the surface finish on the major diameter is usually smoother than on the flanks of the teeth, and that the major-diameter can be controlled easily on external parts and broached internal parts.

The American Standard for Involute Splines also offers guidance to the designer in cases where special conditions preclude the strict application of the standard dimensions. From past experience, it would appear that standard splines can be adapted to meet most requirements. It is urged, therefore, that standard involute splines and serrations should be employed wherever possible, in order to permit the widest use of standard tooling.

INSPECTION OF INTERNAL SPLINES

The inspection of splines and the design of spline gauges is covered by two additional standards. Published by the A.S.M.E., the American Standard for Involute Spline and Serration Gauges and Gauging, B5.31-1953, provides a comprehensive source of information from which a spline inspection system can be evolved. The Commercial Standard CS8-51, published by the U.S. Department of Commerce in co-operation with the National Bureau of Standards, specifies the sizes of standard blanks for involute spline gauges.

It is important that designers, tool engineers, quality control engineers, gauge designers, and inspectors should understand the variables which can affect splined connections, and how such variables can be controlled. Furthermore, it must be emphasized that the correct design of tools and gauges, and control of the spline fit, are wholly dependent upon the correct specifications being given on the working drawings of the parts concerned. In the drawing, Fig. 4, are indicated the important dimensional factors of an internal spline and an external spline, and the gauges used to control these factors.

The previously-mentioned American Standard B5.31-1953 covers all the important types of gauges, and below are illustrated and described those types which are in general use. At *A* and *B* in Fig. 5 are shown paddle-type plug gauges used for controlling the actual space width of an internal spline, and these gauges perform an inspection check similar to a measurement taken between pins. Referring to the type at *A*, the "not-go" paddle gauge checks the maximum actual space width and the "go" paddle gauge checks the minimum actual space width. On this type of gauge, the outer flanks of each pair of teeth are relieved, so that the diametrically opposite spaces only are in contact with the splined part. With this arrangement, the gauge can be inserted regardless of accumulated interference errors.

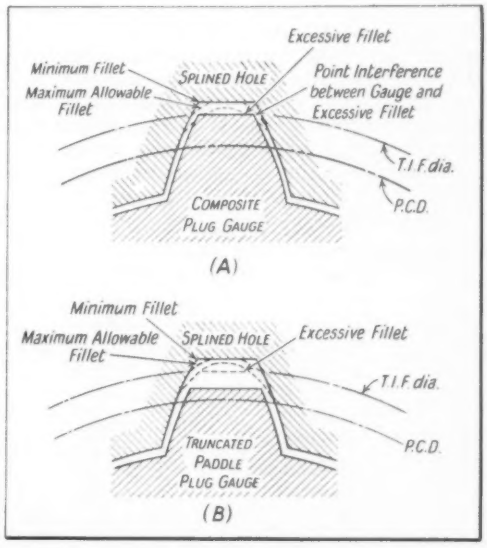


Fig. 6. The "Go" Composite Plug Gauge Seen at *A*, which has the Full Complement of Teeth, will Not Enter the Workpiece Because of Interference Caused by Excessive Fillet Radii. In these Circumstances a "Go" Paddle-type Plug Gauge with a Reduced Diameter is Used, as seen at *B*. Such a Gauge is not Obstructed by the Fillet Radii

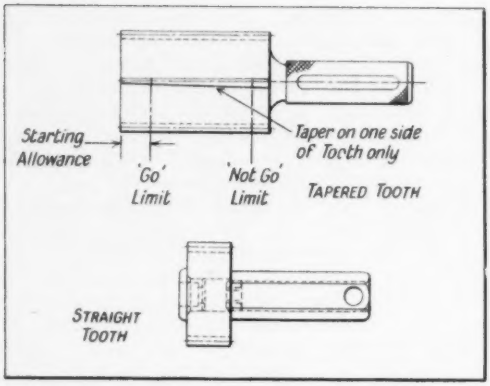
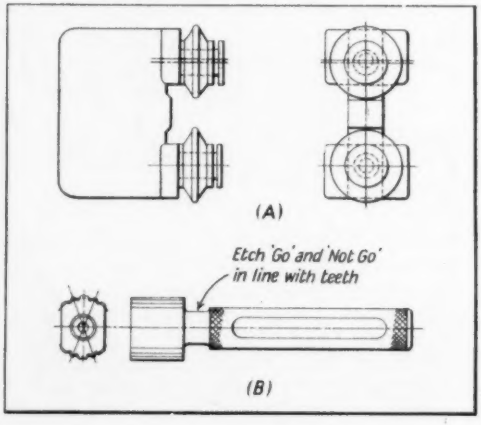


Fig. 7. Straight- and Tapered-tooth Composite Plug Gauges Used for Checking the Minimum and Maximum Effective Space-widths

The tapered-tooth paddle plug gauge seen at *B* is a combination "go" and "not-go" gauge, on which scribed lines are provided to indicate the depths of engagement. This gauge is used on parts for which close tolerances are specified, or where close size control is desired, so that workpieces can be selected within a given size range. Since the tapered-tooth plug gauge measures the actual space width of the splined part, rather than merely establishing its acceptability, it is often preferred to the parallel type of "go" and "not-go" paddle plug gauges.

The major-diameter of a paddle-type plug gauge is reduced, as seen in Fig. 6, to avoid interference with the excessive fillet radii which can be caused by the use of worn or incorrectly designed tools. However, the "go" composite plug gauge is not reduced in this manner, and should these fillet radii extend beyond allowable limits this gauge will not enter the work. The "go" paddle plug gauge is used for further inspection of a part which has been rejected by the "go" composite plug gauge, or to assist in setting-up production equipment. If the "go" paddle plug gauge enters the work, and the "go" composite plug gauge does not, excessive interference errors or excessive fillet radii are indicated.

Fig. 8. The Roller-type Snap Gauge seen at *A* has Eccentrically-mounted Adjustable Rollers and is Set to the Master seen at *B*



Composite spline plug gauges, as shown in Fig. 7, are used to control the effective dimensions. The "go" composite spline plug gauge checks the minimum effective space width, and serves as an acceptance gauge, as it detects interference only, but does not indicate which dimension or relationship is incorrect. A "not-go" composite plug gauge controls the maximum effective space width, but does not control the widths of individual spaces. If the relative positions of the spaces are incorrect, the "not-go" composite gauge may not enter the part, even though all the spaces are over-size. The "not-go" composite plug gauge is used only when the maximum effective space width is given, but is not specified as a "reference" dimension. (See control systems A and B.)

A tapered-tooth composite plug gauge is a combination "go" and "not-go" gauge, with scribed lines to indicate the permitted depths of engagement. This gauge is used for parts which have close tolerances, and, if desired, permits the selection of parts within a given size range. Since the tapered tooth gauge measures the effective space width, rather than merely accepting or rejecting the part, it is often preferred to separate "go" and "not-go" gauges.

INSPECTION OF EXTERNAL SPLINES

For inspecting an external spline, the roller-type tooth thickness snap gauge, seen in Fig. 8, performs a function similar to that of the paddle plug gauge used for the internal spline. This gauge is used to control the actual tooth thickness, in the same manner as measurement made over pins. The "go" roller-type snap gauge is used to control the maximum actual tooth thickness, and the "not-go" gauge, the minimum actual tooth thickness. These gauges have an eccentric adjustment, to facilitate initial setting, and subsequent resetting to compensate for wear, and these adjustments are made to a master, which usually incorporates the "go" and "not-go" sizes.

The indicator tooth thickness snap gauge shown in Fig. 9 is used for both controlling and measuring the actual tooth thickness of external splines, and, as in the case of the roller-type snap gauge, it gives the same result as a measurement over pins. The indicator gauge will check the "go" and "not-go" limits, and, in addition, will indicate the amount and range of manufacturing variations, so that it is superior to the roller-type snap gauge. It is ideally suited for quality control operations, and enables quick and accurate checks to be made, during production, without removing the workpiece from the machine.

The indicator snap gauge has a fixed bottom jaw and a movable top jaw, each being provided with a gauging anvil which has the form of a rack tooth, or teeth, or a cylindrical section of the same diameter as a standard measuring pin. These anvils are interchangeable to accommodate different pitches.

The movable top jaw actuates a dial indicator, which has a cushioned movement and is graduated in divisions of 0·0001 in. A master is used to set the gauge to zero. By a direct ratio, the reading on the dial indicator can be converted to determine the difference between the tooth thickness of the part and that of the master, and this ratio is stamped on each gauge. The master can be made to correspond to the high, low, or mean tooth thickness, or to any combination thereof.

The "go" composite ring gauge, seen at A in Fig. 10, represents the mating internal splined part, and controls the maximum effective tooth thickness. As in the case of a composite plug gauge, the "not-go" composite ring gauge is used only when the minimum effective tooth thickness is given, and is not specified as a reference dimension. (See control systems "A" and "B".)

At *B* in Fig. 10 is seen the tapered-tooth master plug which is used for the control of the ring gauge. An allowance for wear is made—usually 0·0003 in. on space width—and when the ring passes over the large end, or a scribed line on the plug, the gauge has worn beyond the allowable limit, and should be replaced.

It will be noted that a master plug is recommended for controlling a ring gauge, whereas a master ring is not used for controlling a plug gauge. On a gauge of the latter type, measurements for size (over pins), spacing, out-of-roundness and involute form, can easily be made, whereas the inspection of the same dimensions on a master ring gauge presents many problems. In addition, a master plug can be made with tapered tooth thickness, to check the wear of the ring, but it is extremely difficult to manufacture a tapered tooth ring.

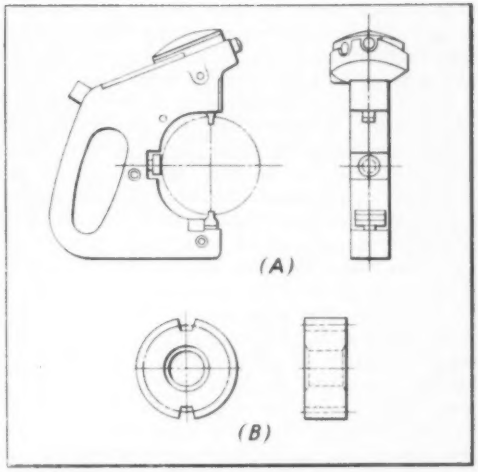
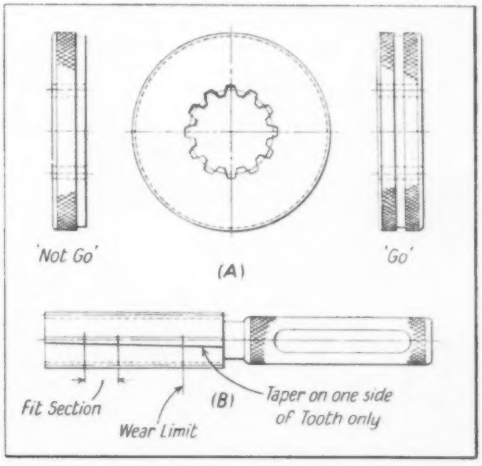


Fig. 9. The Indicator Snap Gauge *A* both Controls and Measures the Actual Tooth-thickness of External Splines. With this Gauge, the Part can be Checked during Production, without being Removed from the Machine. The Gauge is Set to Zero by Means of the Master seen at *B*

Fig. 10. The "Go" Composite Ring Gauge at *A* Represents the Mating Internally-splined Member and is used to Control the Maximum Effective Tooth-thickness. At the Left is a "Not Go" Composite Ring Gauge which is Employed for checking the External Spline when the Maximum Effective Tooth-thickness is Specified, but is not Marked as a Reference Dimension. The Tapered-tooth Master Plug Gauge at *B* is Used for Controlling the Composite Ring Gauge



As a rule, splined members have a tooth flank fit, and the basic group of gauges—plug, paddle plug, ring and snap—that is necessary for checking such a splined connection has been discussed.

When a major-diameter type of fit is specified, gauges and gauging elements for the inspection of critical fit diameters must be added to those already mentioned. In this instance, correct and complete dimensions of fillet radii and chamfers is important. For major-diameter fits, it is necessary to control the amount of eccentricity present between the major diameter and the pitch diameter of the splined connection, and generally this is accomplished by using major-diameter concentricity gauges, as shown in Fig. 11, which will accept or reject the part. If the part is rejected, standard composite plug and ring gauges are sometimes used, to determine the reason for the rejection, which might be due to an error in the effective size of the spline, or to eccentricity of the major diameter in relation to the spline form.

The gauges described above are effective for detecting errors caused by faulty or worn tools, incorrect setting-up, or the use of worn machines. For example, it is possible that a part might be accepted by the "go" snap gauge, accepted partially by the "not-go" snap gauge and rejected by the "go" composite ring gauge. This is an indication that either the interference errors are in excess of those specified on the working drawing or the ring gauge is being arrested by an oversize fillet radius.

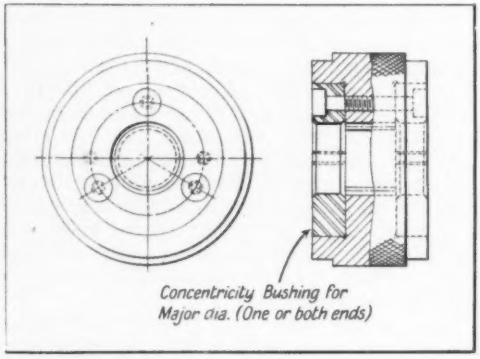


Fig. 11. Composite Ring Gauge for Checking the Amount of Eccentricity Present between the Major Diameter and the Pitch Diameter of an External Major-diameter Fitting Spline. This Gauge has Interchangeable Bushes to Suit Various Diameters

TOOLING AND INSPECTION CHARTS

A typical chart for the production of a pair of flank - fitting splined members is shown in Table 1; in which the factors involved in the control of the fit are listed. The table includes part specifications, gauge tool numbers and sizes; and indicates the tools required, such as broaches,

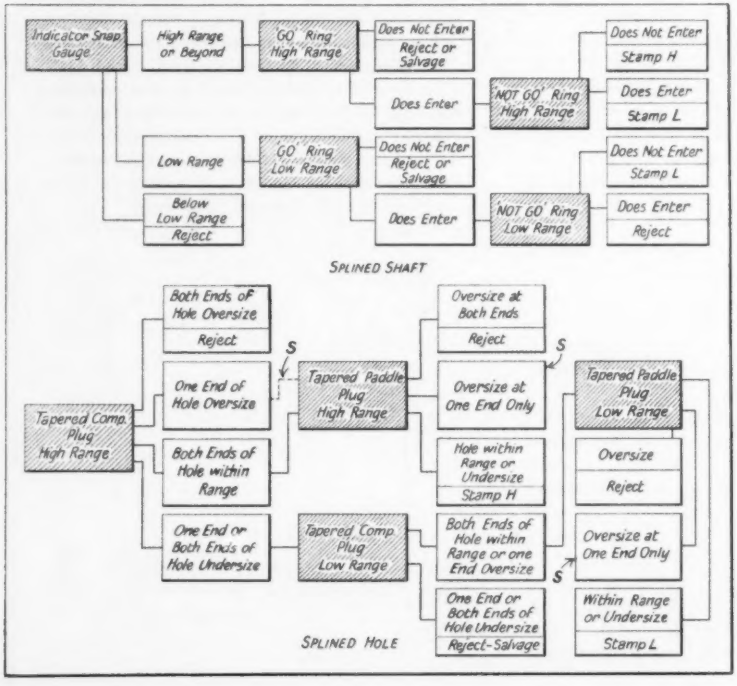


Fig. 12. Inspection Flow Charts for a Splined Hole and Shaft. Parts which Terminate in the Categories Marked *S* Should, Theoretically, be Scrapped, but may be Suitable for Salvage

TABLE 1.—TYPICAL TOOLING AND INSPECTION CHART FOR SPLINED COMPONENTS

	Machine Tools	Part Spec. in.	In-process gauges in.	Type	Finish gauges in.	Involute spline in.	Remarks
Splined hole Part No. 67471	Broachine machine No. BC-671	Max. actual space width 0·0810	Tool No. Tooth thickness	"Not go" paddle plug	Tool No. G-11 Tooth thickness 0·0810	Type of fit. Side—flat root	Only splines showing broaching tear marks are lapped
	Broach No. T-74	Min. actual space width 0·0800	Tool No. Tooth thickness	"Go" paddle plug	Tool No. G-12 Tooth thickness 0·0795	Major dia. clearance max. 0·029 min. 0·014	
	Lap No. T-75	Max. effective space width 0·0795	Tool No. Tooth thickness	"Not go" composite plug	Tool No. Tooth thickness	Backlash Max. 0·0061 min. 0·0005	
		Min. effective space width 0·0785	Tool No. Tooth thickness High Low	Tapered tooth composite plug	Tool No. Tooth thickness High Low 0·0800 0·0785	Minor dia. clearance Max. 0·0265 Min. 0·014	
			Tool No. Tooth thickness	"Go" composite plug	Tool No. G-10 Tooth thickness 0·785		
Spline shaft Part No. 67432	Hobbing machine No. BC-982	Max. actual Tooth thickness 0·0764	Snap gauge No. G-15 Master No. G-16 T.T. 0·0814	"Go" snap gauge and master	Snap gauge No. G-10 Master No. G-16 T.T. 0·0764	Spline data	
	Hob No. T-79	Min. actual Tooth thickness 0·0749	Snap gauge No. G-19 Master No. G-20 T.T. 0799	"Not go" snap gauge and master	Snap gauge No. G-14 Master No. G-11 T.T. 0·0749	No. of teeth 12, pitch 20/40 P.A. 30 deg.; pitch dia. 0·600 in.	
	Shaving machine No. BC-410	Max. effective Tooth thickness 0·0780	Ring gauge No. G-17 Master No. G-18 T.T. 0·0827 W.L. 0·0830	"Go" ring gauge and tapered tooth master	Ring gauge No. G-12 Master No. G-13 T.T. 0·0777 W.L. 0·0780		
	Shaving cutter No. T-91	Min. effective Tooth thickness 0·0765	Ring gauge No. Master No. T.T. W.L.	"Not go" ring gauge and tapered tooth master	Ring gauge No. Master No. T.T. W.L.		Vinco Corp.
						Drn. Ckd. Date	Splined connection chart for parts 67471 67432

hobs, and cutters, and their corresponding identification numbers. Also included is the important fit information, such as minimum and maximum major diameter clearance, minimum and maximum backlash, and all other important spline data. Space is provided for listing gauges which may be needed before heat-treatment, or before a final operation such as grinding. A space is also provided in which any unusual information pertaining to a particular connection can be listed, and tables of this nature serve as central sources of information for spline production.

In Table 2 are included the data for a pair of splined members used in a farm tractor, and the design calls for such a close tolerance—only 0·002 in.—on the effective fit between the two parts that the required manufacturing allowances are greater than the permissible fit variations. To ensure the desired fit, and to maintain interchangeability, it is necessary to establish high and low ranges, into which the parts can be segregated. It will be noted that if advantage is taken of the full manufacturing tolerance, the desired fit will not necessarily be obtained, whereas if the parts are held to the effective dimensions the specified fit will be achieved.

TABLE 2. DIMENSIONS FOR SELECTIVE ASSEMBLY OF SPLINED TRACTOR PARTS

Splined data: 16 teeth; 6/12 pitch; 30 deg. P.A.; 2·667 pitch dia. Effective fit (backlash) between mating parts 0·0005 to 0·0025 in. interference

	Splined Hole Space width, in.			Splined Shaft Tooth thickness, in.		
High range	Max. actual	0·2639		Max. eff.	0·2644	
	Min. actual	0·2629		Min. eff.	0·2634	
	Max. eff.	0·2629		Max. actual	0·2629	
	Min. eff.	0·2619		Min. actual	0·2619	
Low range	Max. actual	0·2629		Max. eff.	0·2634	
	Min. actual	0·2619		Min. eff.	0·2624	
	Max. eff.	0·2619		Max. actual	0·2619	
	Min. eff.	0·2609		Min. actual	0·2609	

Effective dimensions can be determined because it is possible to approximate the extent of the interference errors which will result from any known method of production. As the amount of press fit interference present between these parts is very important, it is necessary to provide gauges that will guard against the parts being "too good," and for this purpose, "not-go" composite gauges are used. (Control system "A"). The inspection flow charts seen in Fig. 12 indicate the sequence of gauging operations for the two parts, and show the destination of the part for each possible gauging result. Each of the various possible routes may lead to a final classification in the high range "H," the low range "L," rejection, or salvage, and where the final decision on the product is to be left to a salvage committee, an S is employed, as shown in the figure. Flow charts of this type will be found extremely helpful in eliminating confusion in the interpretation of inspection results.

Since each manufacturer generally has an individual gauging problem, it is not suggested that the gauges here discussed will be suitable for all situations, nor, on the other hand, that all the gauges shown will be required for every spline gauging programme.

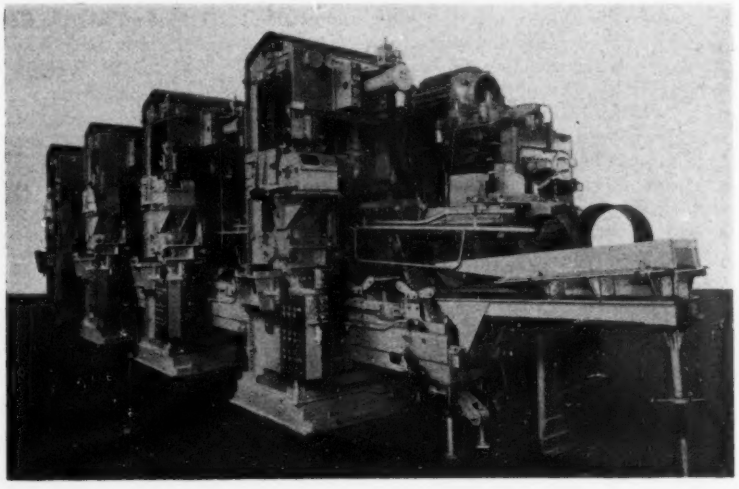
McKay Automatic Rim Rolling Equipment

The latest design of motor vehicle wheel rim rolling equipment, built by the McKay Machine Co., Youngstown, Ohio, U.S.A. (Rockwell Machine Tool Co., Ltd., Welsh Harp, Edgware Road, London, N.W.2), is shown in the illustration, from the loading end. Plants with four units, as shown, or with other numbers, may be supplied, the actual number depending upon the amount of forming to be carried out. Rolling is performed in each unit by two rolls, arranged vertically, the upper roll being fed down automatically during the forming operation by a hydraulically-actuated toggle linkage. Both rolls are supported in anti-friction bearings, and the outer end of the lower roll is held in a socket during the rolling operation. The socket is provided with bearings, and when rolling has been completed the lower roll can be retracted to allow the blank to be transferred to the next unit. At the same time, a new blank is fed into position and the lower roll is then advanced to engage the socket again, so that the rolling cycle can be repeated.

Movement of the rim blanks between successive rolling operations is effected by means of walking beam-type transfer mechanisms which incorporate rollers on which the rims are supported. The movements of these mechanisms are synchronized with the operation of the individual units of the plant by limit switches. Retractable hooks, at the sides of each unit, support the rims in the raised position during the return movement of the transfer mechanism.

Rims can be rolled from prepared blanks at rates of the order of 750 per hour, and a plant with three units, and interconnecting transfer conveyors, occupies a floor space of about 450 sq. ft. Existing rolls can normally be employed in such a plant.

Equipment made by the company also includes machines for rolling blanks in preparation for welding, and for making other components such as lock rings for large detachable rims, such as are used on commercial vehicles.



View from the Loading End of a McKay Automatic Wheel Rim Rolling Plant, Comprising Four Roll-forming Units, with Interconnecting Transfer Mechanisms

Die Casting Supplement

Pressure Die Casting of Necchi Sewing Machine Components

In a previous article, published in MACHINERY, 92/499—28/2/58, the new pressure die casting foundry, which has recently been provided at the Pavia, Northern Italy, factory of Necchi, S.pA., was described, togethed with some of the methods employed for the production of sewing machine components by this method. Very long-established, the Necchi company has always operated its own highly efficient mechanized iron foundry, but since the war has turned increasingly towards the use of pressure die castings, in both aluminium and zinc alloys, in sewing machine construction. Advantage has been taken of the possibilities of the process for the improvement of design and the reduction of manufacturing costs, in connection with the current range of sewing machines, and some very interesting castings are now being produced, two of which are considered in this article.

It may be recalled that the majority of the machines at present installed are of the water-hydraulic type, built by A. Triulzi, S.A.S., of Milan (Alexander Cardew, Ltd., 2-5 Studio Place, Kinnerton Street, London, S.W.1), and they are powered from a central pumping plant. A view in the foundry showing five of these machines, of the cold-chamber type, ranging from 150 to 350 tons capacity, is given in Fig. 1. The machines are arranged in the conventional manner, at an angle of about 30 deg. to the gangway, so that the die openings are not in alignment, and metal splash cannot therefore reach the operator of an adjacent machine. Each machine is served by its own holding furnace, with electric resistance heating, and melting is carried out in a centralized unit which serves the whole foundry. On the

Fig. 1. A View in the New Necchi Pressure Die Casting Foundry Showing Five Triulzi Water-hydraulic Machines of 150 to 350 tons Capacity, for Cold-chamber Casting Aluminium Alloys

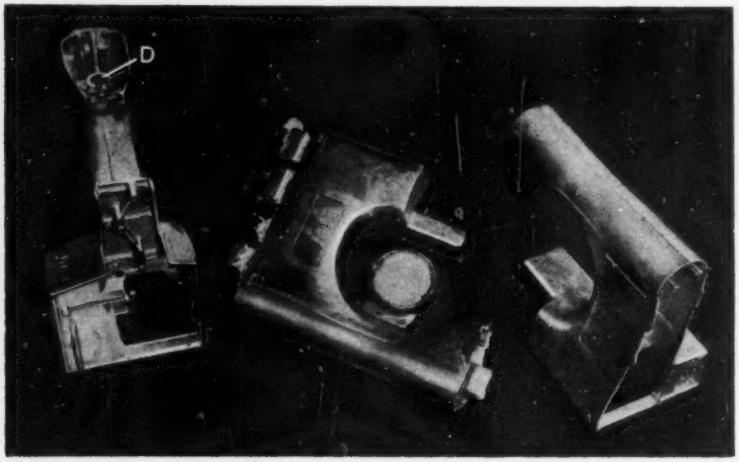


Fig. 2. Three Views of the Combined Arm and Base Casting for the Mirella Domestic Sewing Machine. The Casting has a Trimmed Weight of 4·5 lb. and the General Wall Thickness Ranges from 0·098 to 0·118 in.

right-hand side of the same gangway is installed the largest Triulzi machine, of 750 tons capacity, also two Bühler oil-hydraulic machines of 400 tons, for cold-chamber casting of aluminium alloys. Since this article was prepared, a third Bühler oil-hydraulic machine, of 600-tons capacity, has been installed.

In addition, at the further end of the foundry, there is an area devoted solely to the production of zinc castings, to which reference will be made in a later article. Triulzi hot-chamber machines of 60 and 90 tons and an Idra machine of 80 tons capacity are provided here, the latter being of the self-contained oil-hydraulic type. The foundry has an output of approximately 55 tons of castings per month, of which 40 tons are of aluminium alloy, and the remainder of zinc. All the castings produced are for sewing machines, and the foundry supplies all the needs of the factory. A well-equipped fettling and finishing department is housed in the same building as the foundry, at the further end in Fig. 1, and here several of the more elementary machining operations are carried out, for instance, on arm castings.

DIE FOR MIRELLA MACHINE ARM CASTING

As noted in the article mentioned above, the latest design of sewing machine produced by the company is the Mirella, which is intended for straightforward domestic sewing and darning, and it incorporates a combined arm and bed casting. Some untrimmed Mirella arm castings are shown in Fig. 2, from which the high quality of the surface finish maintained in the foundry may be observed. This machine is intended to be produced at the minimum

Fig. 3. This 750-ton Capacity Triulzi Machine is Employed for the Production of the Mirella Combined Arm and Bed Casting Shown in Fig. 2. The Electrically-heated Holding Furnace at the Right has a Capacity of 350 lb. of Aluminium

price consistent with quality, and the bed portion of the one-piece castings encloses the shaft drive to the shuttle mechanism. The casting also has a projection on one side, seen most clearly in the example on the left, which houses the driving motor. Thus, almost all the mechanism is enclosed in a single casting, so that the work of the machine and assembly shops is greatly simplified.

Since the casting is of intricate shape, it is made in the more free-running of the two alloys employed as standard in the foundry, which contains 10 to 11 per cent of silicon, castings of simpler form being made from aluminium containing 8·5 to 9 per cent of silicon. The die is normally fitted to the Triulzi type 16,000 machine, of 750 ton capacity, shown in Fig. 3, which is of all-steel construction and has a large-diameter water-hydraulic cylinder at the left-hand end to apply the pressure for closing and locking the die. There are two smaller cylinders for opening the die, and provision is made for the hydraulic operation of core slides by means of telescopic tubes at the top of the machine. For this and the other large capacity machines, holding furnaces with a capacity of 300 to 350 lb. of aluminium alloy are employed, each of which has a current capacity of 22 kW.

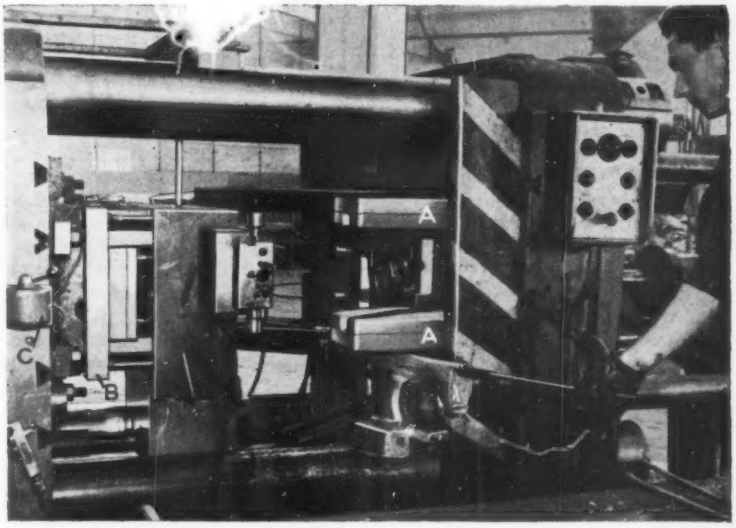


Fig. 4. Close-up View of the Die for the Mirella Casting, Showing Details of the Fixed Half, and the Projections *A*, which Incorporate Cam Tracks for the Movement of the Side Cores

A close-up view showing the die open, with the fixed half on the right and an arm casting in the foreground, is given in Fig. 4, and it will be seen that the two horizontally-moving core slides in the moving half are actuated, for part of their travel, by cam grooves in upper and lower projecting bars. The bars for the core slide at the front of the die are indicated at *A*, and there are two similar bars at the rear, for the other core slide. Cam grooves in the opposed faces of each pair of bars are of square section and they are engaged by rollers on the upper and lower surfaces of the core slide extensions as the dies are closed. During the last part of its inward movement, each core slide is engaged by cam pins of conventional type, on the fixed die member, to provide a more positive closing and retracting action and it is finally backed up by an inclined surface on the fixed die, against the pressure of the injected metal.

From Fig. 4 it will be seen that there are two other cam pins, of heavy section, projecting downwards from the fixed die, and these pins are employed to operate a vertically-moving core slide. Hydraulic ejection of the casting from the moving die cavity is effected, on the Triulzi machine, by means of a small cylinder within the ram of the main die locking cylinder, with which it is concentric. The ram of this small cylinder is connected to a plate *B*, carrying the ejector pin holder, and it is operated by a solenoid valve controlled by the switch *C*. At each corner of the plate *B* there is a projecting ear to which the return pins are attached, and to the upper ear, on the side shown, a small cam plate is secured in a horizontal position. Fixed to the die, alongside this cam plate, is a micro-switch, which forms part of the control circuit of the machine, and when the ejector plate *B* is in the advanced position, the small cam operates the switch, interrupting the circuit, so that the die cannot be closed.

Another view of the die, showing the moving half, is given in Fig. 5, from which the shapes of

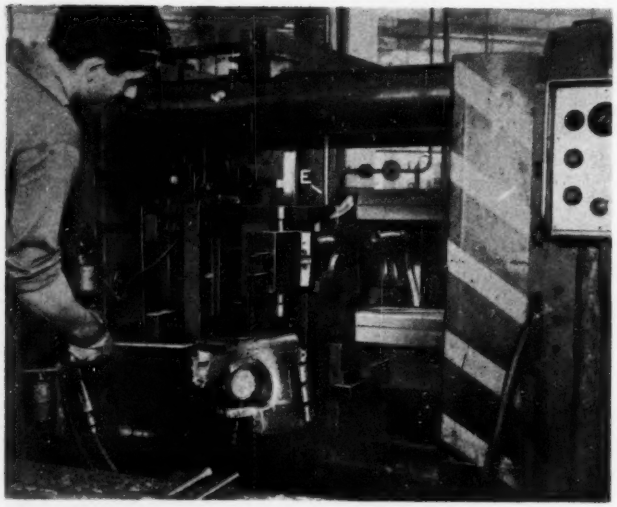


Fig. 5. Details of the Moving Half of the Die for the Mirella Arm Casting may Here be Seen. The Weight of the Overhanging Portion of the Die is Supported by a Bar *E* from a Cross-member Above

the cores carried on the various slides may be observed. In the casting at the left in Fig. 2, the shape of the cavity produced by the vertically-moving core can be observed, and it will be noted that it forms a number of bosses and other projections within the bed portion and the motor housing. In addition to mounting positions for the driving motor, there are bosses for the attachment of a casting carrying the shuttle mechanism and shroud, and a base casting on which the completed machine is supported. A row of six horizontal air vent slots in the inclined surface of the motor housing, which faces upwards on the casting on the left in Fig. 2, is cored by fixed projections from the face of the moving die member. On the far side of the vertical core there is a flat surface which, in the casting position, is in contact with a matching surface on the core at the rear of the die. An aperture is thus formed in the end of the casting which, in the finished assembly, accommodates a die cast plate carrying certain sewing controls.

The core on the horizontal slide at the far side of the die also serves to form the cavity in the arm, which houses the driving mechanism for the needle shaft, and, in conjunction with the vertical core, to form a recess in the end face of the motor housing. On the slide at the front of the die is carried a core for forming the opening in the needle bar end of the casting, also an internal cored boss for the needle bar driving shaft. This cored boss is supported by ribs on the inside of the head portion of the casting, and is indicated at *D* in Fig. 2. On the Triulzi machine, the weight of the moving platen is supported on rollers at the bottom, which run on flat ways machined on the base casting, in the conventional manner. Since the moving die half is heavy and has a considerable overhang, additional support is provided by means of the suspension rod *E*, Fig. 5.

This rod is screwed into the upper surface of the die block and has adjusting nuts at its upper end, which passes through a cross-bar supported on the upper pair of tie bars of the machine. The cross-bar is connected by straps to the top of the moving platen so that it is always in a position directly above the die member during the opening and closing movements of the machine. The fixed guard at the right in Fig. 5 is typical of the safety precautions taken in the plant and covers the parting line of the die to intercept metal splash. Such guards are painted with diagonal black and yellow stripes, and they accompany the particular dies when they are moved to the maintenance area, or into the stores.

From an examination of the castings shown in Fig. 2, and elsewhere, it will be apparent that the cavity is centre-gated at a position directly above the plunger hole, the gate leading into the underside of the arm casting. Such gates have lengths up to 4 in. for large castings, but for the Mirella arm the length is slightly less. Normally, the minimum thickness of metal in an aluminium casting is 2 mm. (0·078 in.), and the average is 2·5 to 3 mm. (0·098 to 0·118 in.). For such unstressed parts as covers, where the casting resembles a pressed part, the thickness may be reduced to as little as 1·5 mm. (0·059 in.). The casting here described has a trimmed weight of approximately 4·5 lb., and the shot weight is about 5·5 lb. A shot sleeve with a diameter of 90 mm. (3·5 in.) is employed, and the maximum force exerted on the metal is 58·4 metric tons.

The cycle of operations on the Triulzi machine is controlled by push-buttons on the panel mounted on the fixed platen, at the right in Fig. 4. On this panel there are buttons for controlling the die-closing movement, and after the operator has filled the sleeve he initiates the forward movement of the injection plunger. For the arm casting, a dwell

time of 16 sec. is required, and an output of 30 to 35 castings per hour is obtained.

DIE FOR SUPERNOVA MACHINE ARM CASTING

As described in MACHINERY, 88/429—13/4/56, in the third of a series of articles on the methods employed for machining sewing machine components in the Necchi factory, the Supernova zig-zag stitch sewing machine is one of the most advanced in the world. This machine incorporates an arm casting of intricate design, which, in the final assembly, is mounted on an iron base made in the mechanized foundry, and, again, the more free-running of the two standard alloys is used for arm production. The arm casting is made on the 400-ton capacity Bühler oil-hydraulic machine shown in Fig. 6, which is completely self-contained, and is served by a holding furnace of similar capacity to that provided for the large Triulzi machine. Some mention was made in the previous article of the arrangements for handling castings and scrap in the Necchi die casting foundry, and the bench in front of the machine in Fig. 6 is an example of the equipment provided. This bench has a wooden surface immediately in front of the position at which the operator is standing, so that the casting taken from the die may be put down, for the purpose of breaking off the flash and the overflows, without damaging the surfaces.

Beneath this wooden surface, which is carried by an angle-section steel frame supported on legs, is a steel tray, shaped to form a chute at the side nearest to the camera. The pieces broken from the casting are dropped on to the tray, and can be swept down the chute, when sufficient have accumulated, by the gloved hands of the operator, and they fall into a large wire mesh box pallet in which they are returned to the centralized melting area. Castings are placed in a similar pallet at one side, for transfer to the fettling department of the foundry, which is housed in the same building. Some details of the Bühler machine were given in the previous article, and it may be recalled that it is of conventional four tie-bar construction, the moving platen being actuated through double toggle links by a hydraulic cylinder. Although the stated die-closing force exerted by this machine is 400 tons, it has been found that this is a conservative figure, and that the machine can, in fact, be subjected to overloads of as much as 20 per cent.

A close-up of the die employed for the Supernova arm casting, from the operator's side of the machine, is given in Fig. 7. The die dimensions are such that it can only just be accommodated on this machine, which has a mounting space of 23 by 22¼ in. Extensions to the die block on the top and at each side carry core slides, and there are two additional slides at the lower side of the die. Certain of the cores carried by these slides are interlocked with each other, in the casting position. The lower slides are moved by cam pins, and the remainder are operated hydraulically, and are locked in position by inclined surfaces when the die is closed. In addition to the moving cores there are two loose cores, which are duplicated to facilitate production, one set being removed from the casting during the next automatic cycle of the machine.

One set of loose cores is seen resting on the

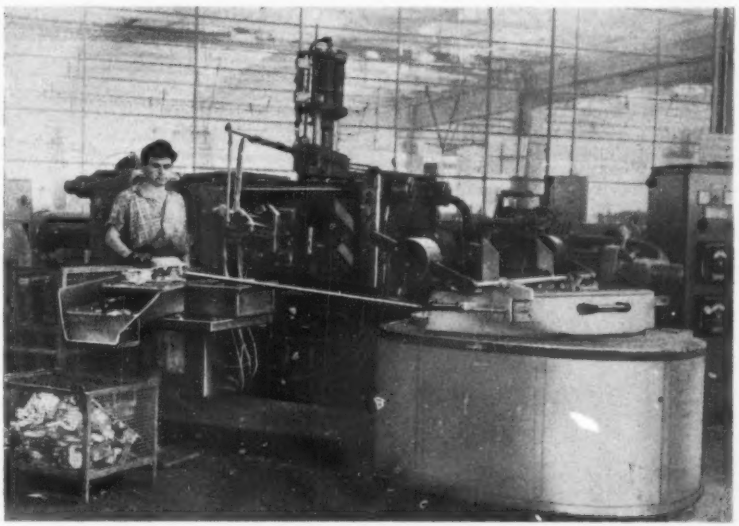


Fig. 6. General View of the Bühler 400-ton Capacity, Oil-hydraulic Machine, Employed for Casting the Arm for the Supernova Sewing Machine. The Bench in the Foreground is Arranged for Easy Disposal of Runner Bars and Other Material

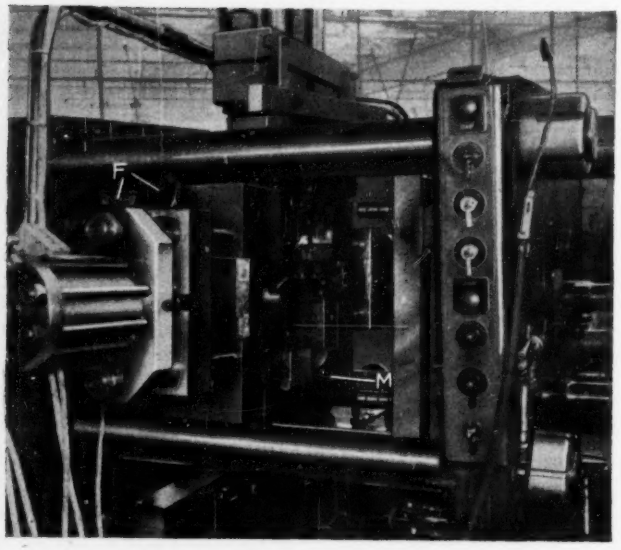


Fig. 7. In this View, from the Operator's Side of the Bühler Machine, Details of the Cores in the Moving Half of the Die for the Supernova Arm may be Observed. The Two Loose Cores at *F* are Loaded into the Die by the Operator

hydraulic cylinder mounting at *F* in Fig. 7, and they may also be seen at *G* and *H* in Fig. 8, where castings produced in the die are shown in various positions. The other set of loose cores is seen in position in the casting in the right background of Fig. 8, and they are employed to form the internal surfaces of two portions of the casting, also the under-sides of two internal undercut bosses, one on each side. Each of these bosses is cast with a blind hole formed by a core peg on the under-side of the upper core slide. The smaller loose core *G* is held in position in the die cavity by means of a peg, which enters the elongated hole in the side seen uppermost in Fig. 8. This peg projects from the face of that portion of the die which forms the opening *J* in the front surface of the arm casting, through which the loose core is just visible.

The core *G* is prevented from turning on the peg by a surface on the core carried on the upper vertical slide, when the latter is lowered into the casting position. The other loose core *H*, Fig. 8, is engaged, at its upper end, which is towards the camera in this view, with an L-shaped locating aperture in the core on the upper slide, and is additionally positioned and supported by a surface on the horizontal slide at the operator's side of the machine. These two cores are advanced into the casting position, under the control of the operator, when the loose cores are being inserted, before the die is finally closed. Other projections and bosses, without undercuts, are formed within

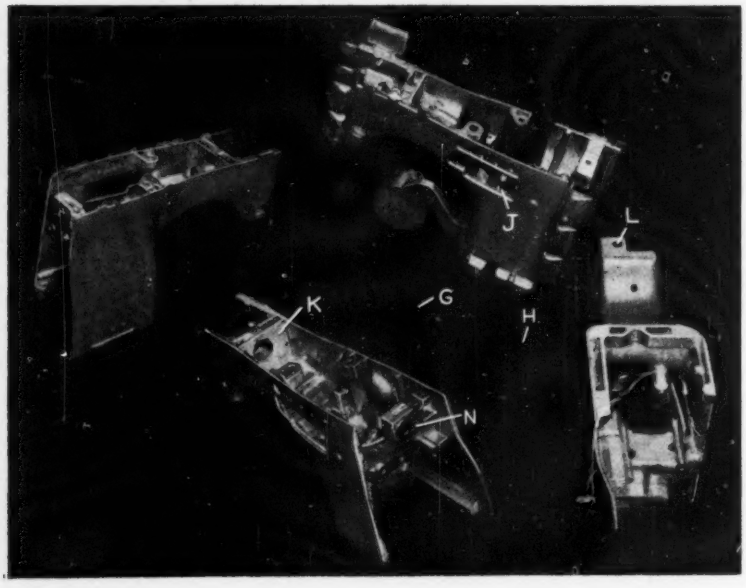


Fig. 8. Four Supernova Arm Castings from the Die in Fig. 7, and the Two Loose Cores *G* and *H*. The Second Set of Loose Cores is in Position in the Casting at the Upper Right

the opening in the top of the arm casting by cores on the upper slide. This opening is closed by a die cast cover in the finished sewing machine, and the arrangement has enabled the casting design to be simplified, and permits access to the mechanism during and after assembly.

Various surfaces and bosses, including a cross-member with a cored hole for the needle driving shaft, indicated at *K* in Fig. 8, are formed by cores on the horizontal slide at the rear of the die, as seen in Fig. 7, in conjunction with the cores on the upper slide. The needle bar hole *L*, Fig. 8, is cored by a slide at the bottom of the die, indicated at *M* in Fig. 7, which is operated by a single cam pin. This slide carries a core which passes through a vertical hole in the main die block. Cores carried by the other slide at the bottom of the die form a heavy-section flange round part of the substantially-square opening at the base of the column portion of the arm casting, whereby it is secured to the cast iron base plate.

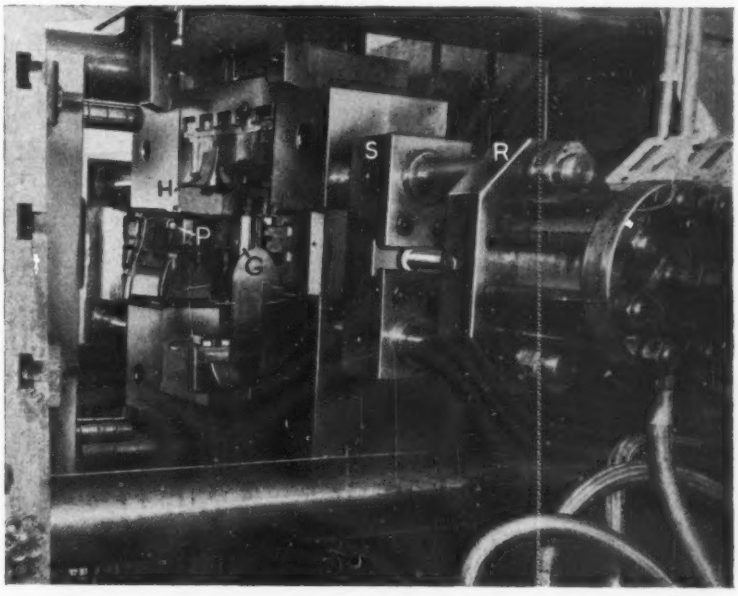


Fig. 9. Taken from the Rear of the Machine, this Photograph Shows Details of the Horizontal Core on the Operator's Side, and the Loose Cores Positioned at *G* and *H*, in Readiness for the Advance of the Hydraulically-operated Core Slides

Another view of the die, from the rear of the machine, is given in Fig. 9, where the two loose cores, identified by the same letters as in Fig. 8, are seen in position. Details of the cores carried on the slide at the operator's side of the die can also be observed in this view. Surfaces within the square-section column portion of the casting are formed by this core, in conjunction with the large core beneath the die, and the cores on the upper slide. In this space there is a boss *N*, Fig. 8, with a steel bush insert, which is cast in position to form a bearing for the rear end of the driving shaft for the needle bar. When the loose cores are inserted in the die, the bush is placed over a mandrel on the core carried on the slide at the operator's side of the machine, indicated at *P* in Fig. 9.

Each of the hydraulic cylinders whereby the core slides are moved is mounted on the ends of two cylindrical bars by means of a plate, which forms the end of the cylinder, one of these plates being indicated at *F*, Fig. 9. This plate is fixed relative to the die and has an opening through which the hydraulic ram passes. The mushroom-headed end of the ram is engaged in a T-slot in the face of a plate *S*, to which the core slide is attached. At the far side of the plate S there is a length of round bar, which is mounted so that it is parallel to the cylinder ram, and carries a cam at its outer end. As the cylinder ram moves the core slide, this bar is moved and the cam operates one of two limit switches depending whether the core is in the advanced or retracted position. The circuits to the switches on the fixed platen at the operator's side of the machine, at the right in Fig. 7, whereby the machine is controlled, are so arranged that the machine must be operated in the correct sequence.

After placing the loose cores and the bush insert in position, as described, the side cores are moved inwards, and, until they are fully advanced, the

upper core cannot be operated. With all these cores in the casting position, and with the hydraulic ejector cylinder retracted, the die can be closed. The sleeve is then filled, by means of a ladle, from the holding furnace, and the injection plunger is operated.

On this machine, injection takes place in three stages. After a preliminary movement, during which the end of the plunger passes the sleeve hole sufficiently slowly to permit escape of air and avoid metal spurting out, a hydraulic accumulator is connected to the plunger-operating cylinder. The plunger is then advanced more rapidly, so that the die cavity is filled with the minimum of premature solidification, and a high-pressure pump is finally brought into operation to increase the pressure during the solidification period.

These stages follow automatically after a switch has been operated to initiate injection, and the final pressure, which is intended to reduce porosity and improve the micro-structure of the cast material, is maintained for a pre-set period. For the Supernova arm casting, this period is 28 sec. This casting weighs approximately 3 lb. in the trimmed condition, and the machine is arranged to operate at the rate of about 25 to 27 cycles per hour.

After the dwell period of 28 sec., the die is opened automatically, the injection plunger is withdrawn, and the vertical slide is then retracted, followed by those at the sides. The ejector cylinder is finally actuated to advance the ejector pins, which operate mainly on the metal which has solidified in the overflow cavities surrounding the main die impression, so that marking of the casting surfaces is avoided. Some of the impressions of the ejector pin ends can be seen on the overflows of the casting at the upper right in Fig. 8.

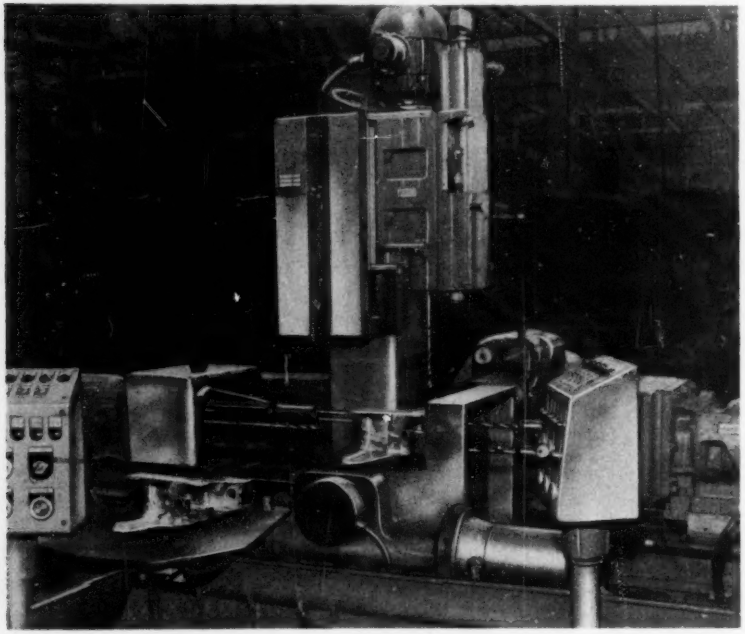


Fig. 10. This Special Machine, Designed and Built by the Necchi Company, and Incorporating Their Own and Proprietary Makes of Unit Heads, is Employed for the Removal of Flash from Cored Holes in the Supernova Arm

FETTLING OPERATIONS

As mentioned earlier, fettling operations are carried out in an area of the building adjacent to the foundry, so that no scrap material leaves the foundry apart from that removed during the light machining operations performed in the main part of the factory. Work which is carried out in the fettling shop includes the removal of external flash and overflows, the smoothing of casting surfaces, where required, on abrasive belt machines, and the clearing of flash from casting apertures and holes. For the latter purpose, special drilling machines are employed, the castings being passed from one to another by a flow-line system. One of these machines is seen in Fig. 10. Designed and built by Necchi, they incorporate standardized unit heads of the Delta-Milwaukee (Gaston E. Marbaix, Ltd.) type, among others, also Necchi unit heads as described in MACHINERY, 88/120—20/1/56. These latter heads incorporate Olivetti quill units, and are arranged for pneumatic feed with hydraulic control.

A close-up view of the fixture on the machine

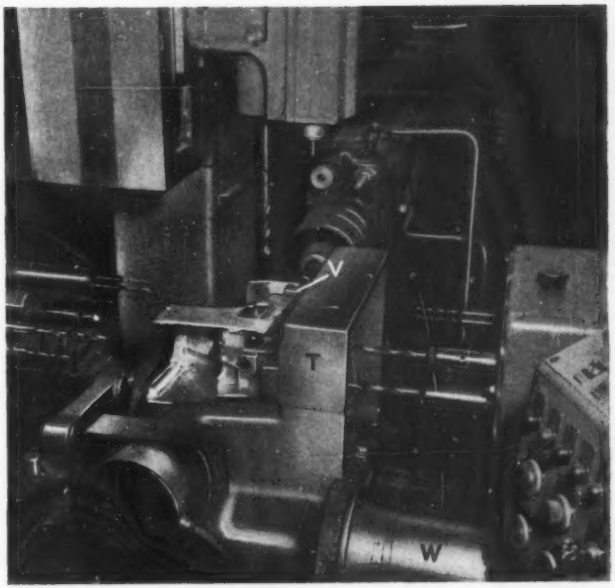


Fig. 11. Close-up View of the Machine in Fig. 10, Showing Details of the Tooling and of the Method of Locating and Clamping the Casting. The Delta-Milwaukee Unit Head, at the Rear, Clears the Steel-bushed Crankshaft Hole in the Casting

is given in Fig. 11, and it incorporates a vertical buttress *T*, against which the casting is placed by the operator. Projecting from the face of the buttress is a locating pad which makes contact with the face of the boss *N*, Fig. 8, and a dowel pin on the pad enters a cored hole in the boss. This hole can be more plainly seen in the casting at the upper right in Fig. 8, and it serves to position the casting in both the vertical and horizontal planes.

At the farther end of the buttress there are two U-shaped locating projections, fitted with adjustable pins and lock-nuts, the upper projection being seen at *V*. The pins are spaced to suit the thickness of the casting walls and engage both edges. Other surfaces on these projections, and on the locating pad for the boss at the front end of the fixture, serve to position the casting edges in the other horizontal direction.

The casting is pressed against these surfaces by a swivelling clamping arm, fitted with a universally - mounted pressure pad, which is swung upwards into contact with the central portion. This clamping arm is carried on a horizontal shaft, which is turned, through a rack and pinion arrangement, by means of an air cylinder, part of which is seen at *W* in Fig. 11. Of weld-fabricated steel construction, the base of the machine is T-shaped in

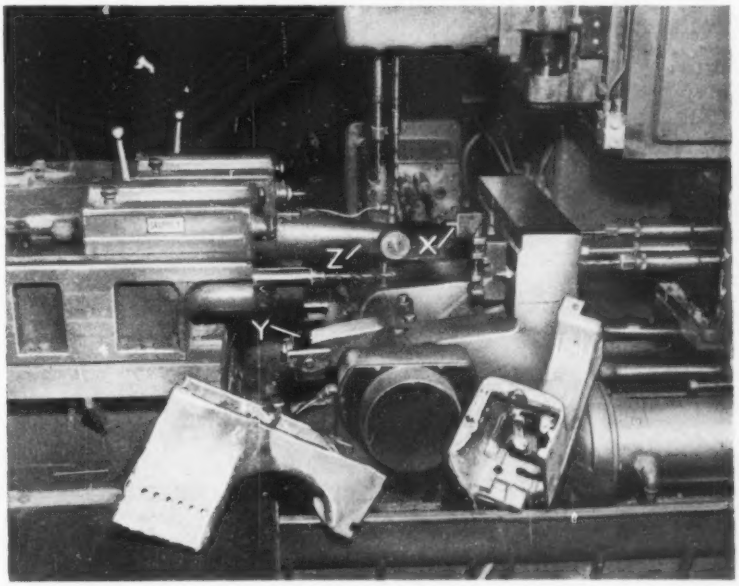


Fig. 12. This Second Necchi-built Machine is Employed for Other Flash-clearing Operations on the Supernova Arm Casting, Including the Trimming of a Cast Slot by Means of the Cutters on the Head Extension at *Z*

plan and the unit head at the right-hand side is fitted with a four-spindle adapter, which carries drills for removing the flash from four cored holes, two at each end of the component. At the rear of the machine there a Delta-Milwaukee head, with a drill for clearing the large hole in the cross-member *K*, Fig. 8. Drills in the multi-spindle adapter on the head at the left in Fig. 11 are employed to clear holes near the head end, the connecting rod hole, and the entry hole for the electric lamp cable, also to machine a face within the square-section column portion of the casting. A single drill in the vertical head, which is carried on a column secured to the side of the rear bed extension, serves to clear a hole within the casting, for the thread-tensioning mechanism of the machine.

The automatic cycle of this machine is controlled from the push-button station at the right in Fig. 11, and when the casting has been unloaded it is passed to a similar, adjacent machine, a close-up view of which is given in Fig. 12. The fixture on this machine is seen unloaded, and, apart from the fact that the casting is here inverted, the loading and clamping arrangements are generally similar to those described in connection with the machine seen in Fig. 11.

A dowel peg which enters the hole in the boss *N*, Fig. 8, is seen at *X* and the clamping arm, in the retracted position, at *Y*. The right-hand head on this machine clears holes for the zig-zag stitch mechanism, and the rear head operates on the bush insert for the crankshaft, and holes for the stitch regulator and the bobbin winder cover support stud, all of which are located in the square-section end of the casting. A multi-spindle, vertical head carries nine drills which operate on the cored holes near the base of the column for air circulation to cool the motor, and for the attachment of a name-plate.

At the left-hand side of the machine there are two heads, and the head at the front is equipped with a single drill for clearing the presser bar hole. The head at the rear is provided with a right-angle attachment *Z*, which carries two small slot-milling cutters. These cutters operate on the sides of the slot within the square-section column of the casting, through which the connecting rod passes in the assembled sewing machine. With these two machines, almost all the cored holes in the casting are quickly and efficiently cleared of flash and much tedious hand work is eliminated.

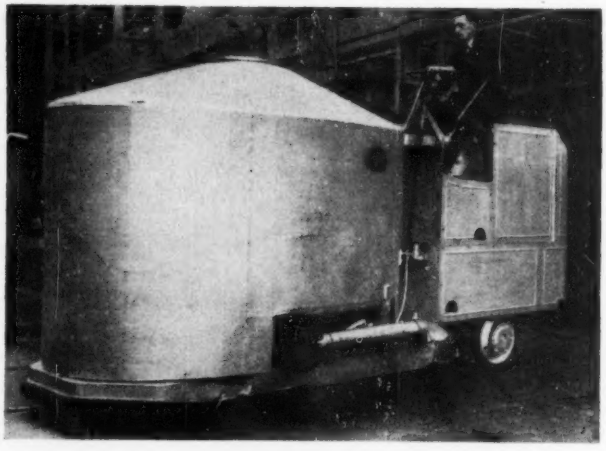
In a further article, to be published in a future issue of MACHINERY, reference will be made to certain castings produced from zinc alloys in a separate area of the foundry.

Greenbat 5-ton Electric Battery Truck with Automatic Elevating Platform and Hopper

Greenwood & Batley, Ltd., Armley Road, Leeds, have recently built the 5-ton electric battery truck with automatic elevating platform and hopper, shown in the accompanying illustration, for a Canadian aluminium works. Aluminium powder is loaded into the hopper, which is then transported by the truck, and elevated so that the powder can be discharged by fan, through the outlet nozzle, into a furnace.

The truck is of the 6-wheel type, with twin articulated trailing axles, and the solid rubber tyres on the two driving wheels are 20 in. diameter by 5 in. tread, and on the four trailing wheels, 10 in. diameter by 5 in. tread. The platform measures 60 in. long by 26½ in. wide and has a carrying capacity of 5 tons. In the lowered position the height of the platform is 10¾ in., and the amount of lift is 5¾ in.

Car-type steering is provided for all six wheels, and the maximum speed on the level, with full load, is 4 miles per hour. Transmission is through worm and worm wheel, with differential universal joint drive to the wheels.



Greenbat 5-ton Electric Battery Truck, with Automatic Elevating Platform and Hopper

The Sixth Factory Equipment Exhibition

As on previous occasions, a wide range of products was shown at this year's Factory Equipment, Heating, Ventilating and Thermal Insulation Exhibition—the sixth in the series—which was held recently at Earls Court, London. In this article attention will be drawn to some of the exhibits likely to be of particular interest to readers of MACHINERY.

Of French origin, the Promecam hydraulic upstroking bending and folding press, illustrated in Fig. 1, was demonstrated by Broadway Equipment, Ltd., 194-196 Finchley Road, London, N.W.3, who have recently been appointed selling agents in this country. The press is one of a range, with capacities from 20 to 150 tons, which Baker Perkins, Ltd., Peterborough, will shortly start to make under licence. Beam lengths vary from 47¼ to 118 in., according to the capacity of the press, and maximum widths from 27½ to 98½ in. can be passed between the side members of the frame. The maximum distance obtainable between the upper and lower beams is 7⅞ in. on the 20-, 30- and 40-ton presses, and 11⅛ in. on the larger sizes. Packing pieces are available for attachment to the upper beams of the larger presses, which enable the maximum daylight obtainable to be reduced to 7⅞ in.

Operated by hydraulic cylinders, ranging up to five in number, the upstroking lower beam has a maximum travel of 3⅛ in., and is accurately guided by a patent arrangement of roller bearings. The operating cycle is controlled by means of a treadle bar, and stepless-variation of the working pressure, also of the stroke and height of the lower beam, can be obtained by a knob and handwheels, conveniently grouped at one end of the bed.

Another exhibit on this company's stand was a Dutch-made fully automatic polishing and grinding machine, which is available in various sizes for handling straight drawn steel tubes with maximum lengths from 3 ft. 3 in. to 19 ft. 6 in. Other equipment handled by the company, which was displayed, included the German-built Lindemann type 57 tube-notching machine.

The Modernair range of compressed air and hydraulic equipment made by Hydraulics & Pneumatics, Ltd., Villiers Street, Wolverhampton, was represented by examples of the recently-introduced MV series valves, which are available with a variety of operating mechanisms for use with system pressures up to 200 lb. per sq. in. A 1¾-in. bore cylinder, arranged for stud mounting, which was on view, is also suitable for use with compressed air and hydraulic systems up to 200 lb. per sq. in., and can be supplied with various stroke lengths up to 24 in. Other items displayed included a selection from the Provenair series of air cylinders which are made with 2, 3, 4 and 6 in. bores. Fixing brackets of various designs can be supplied which enable different mounting arrangements to be obtained.

A new product exhibited by Berridge Aircraft, Ltd., Berridge Road, Hyson Green, Nottingham, is an automatic heavy-duty paint spraying unit, known as type A.S.M., for handling parts up to 20 in. diameter by 20 in. high, with weights up to 50 lb. If required, a conveyor system can be provided for transferring sprayed components to a drying oven. The recently-introduced type J paint spraying equipment, shown in Fig. 2, which was also on view, is available with hand or power indexing of the work-holder, and with fixed and traversing spray guns. It can also be provided with fume extraction equipment as shown. Another exhibit was a paint spraying and stoving unit which incorporates a chain-type conveyor fitted with a take-up mechanism, whereby the work spindles are caused to dwell when the parts have

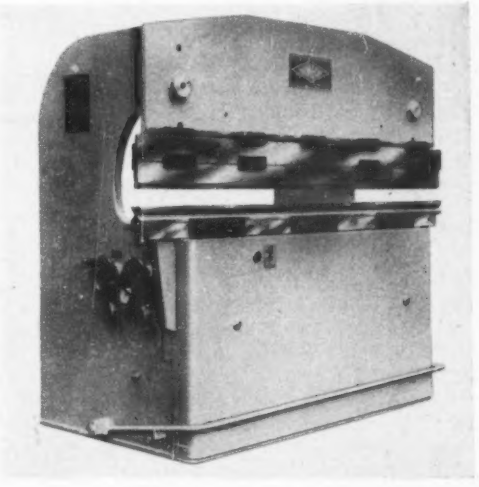


Fig. 1. Promecam Hydraulic Up-stroking Bending and Folding Press

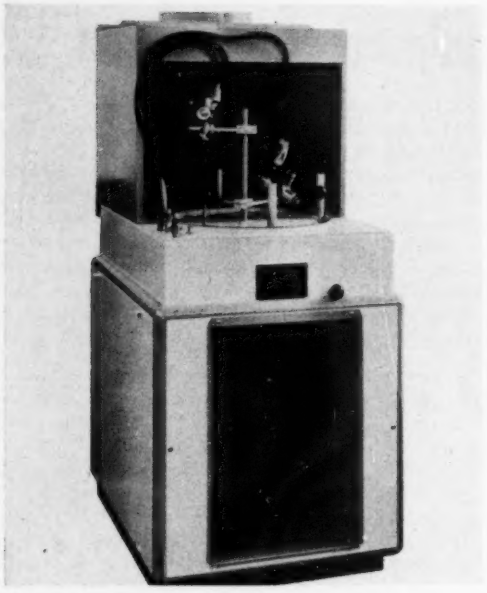


Fig. 2. Berridge Type J Paint Spraying Machine with an Indexing Work Holder

been brought to the spraying position. Apart from loading and unloading of workpieces, which can be carried out by one operator, the equipment is entirely automatic in operation.

Four recent additions to their range of Surform hand tools were included among the exhibits of Simmonds Aerocessories, Ltd., Treforest, Glam. These new tools comprise a fine-cut file, a half-round file, a block plane, and a convex plane, and, like the well-established standard plane and file, they incorporate the special perforated blades developed and supplied by Firth Brown Tools, Ltd. The blades give controlled depth of cut with light pressure, and cuttings pass through slots between the teeth so that clogging does not occur.

E. P. Barrus (Concessionnaires), Ltd., 12-16 Brunel Road, London, W.3, showed the 3-in. capacity portable pipe bending machine, illustrated in Fig. 3. This machine has recently been added to the Blackhawk Porto-Power range of hydraulic equipment which they handle. It enables pipes to be bent through angles up to 90 deg. at a single setting, and is supplied with formers of different sizes to suit pipes down to 1¼ in. diameter.

Other new additions to this range, which were displayed, are Hole-O-Ram hydraulic cylinders in capacities of 20, 30 and 60 tons. Incorporating a hollow ram, which may be fitted with an internally threaded sleeve to take an adjustable spindle, for example, the cylinder enables pulling and pushing actions to be obtained simultaneously. Pullers of various designs are available for use with the cylinders to facilitate removal of bearings and pulleys. Alternatively, a pad with a serrated top surface can be inserted in the ram; in place of the sleeve, and the cylinder can then be used as a jack.

On the stand occupied by Watson, Manasty & Co., Ltd., 139 Richmond Road, Kingston-on-Thames, Surrey, prominence was given to some examples of the "optacology" charts made by the company for use on their Shadomaster optical projectors, to permit a number of workpiece dimensions to be checked simultaneously to a high degree of accuracy. The Shadomaster type CRP Mark 2 projector, shown in Fig. 4, is fitted with an "optacology" chart for checking a total of nine dimensions on a very small component which was produced on an automatic screw machine. Intended for attachment to the screen of the projector, the chart is provided with black-coloured castellated bands which correspond to the shape of the magnified image of the workpiece. The depths of the castellations represent the tolerance boundaries for the component. With this arrangement, the workpiece image is compared with the clearly-defined edges of the bands and the need for taking line thickness into account is obviated.

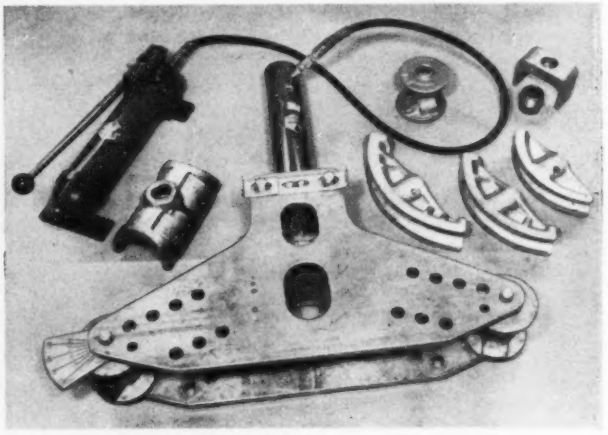


Fig. 3. Blackhawk Porto-Power Hydraulic Bender for Pipes up to 3-in. Diameter

Fig. 4. Shadomaster Type CRP Mark 2 Projector Fitted with an Optacology Chart for Checking Nine Dimensions on a Small Component

so that dimensions with close tolerances can be readily checked.

For the production of the charts, a negative, in the ratio of 1 to 1, is first prepared on coated or plastics sheeting by an automatic remotely-controlled machine of the company's design. On this machine, the marking heads are traversed across the sheet, and are automatically raised clear intermittently, for producing the castellated bands. The shape of the negative is then reproduced, photographically, at the same size, on a glass plate with an emulsion film, which forms the "optacology" chart.

Shown in Fig. 5 is the new 20-ton hydraulic press which was exhibited by Tubela Engineering Co., Ltd., Fowler Road, Hainault, Ilford, Essex. Suitable for such operations as pressing, stretching and bending, it incorporates a lever-actuated 3-speed hydraulic pump which gives ram movements of $\frac{1}{16}$, $\frac{3}{16}$ and $\frac{5}{16}$ in. per working stroke. The total ram travel is 10 in. and the counterbalanced work-table can be adjusted vertically to give a maximum daylight opening of 38 in. Of fabricated steel construction, the frame has an overall height of 81 in., and occupies a floor space of 42 by 30 in. The distance between the side members of the frame is 36 in., and the crown carries a flush-mounted pressure gauge.

Dallow Lambert & Co., Ltd., Thurmaston, Leicester, displayed a representative selection from their wide range of dust control equipment which finds numerous applications in a variety of industries. The firm's Dustmaster dust collecting units, examples of which were shown, are noteworthy for the fact that they are built up from a standard range of fans, filters and containers, so that as many as 120 types can be provided for dealing with different types of dust resulting from a diversity of industrial processes. In Fig. 6 is shown a Dustmaster type D.M. 101 dust collecting installation for a milling machine which is set up for operations on cast iron components.

An MG 60 type A wet deduster was exhibited as representative of a range covering 13 sizes, with capacities from 2,000 to 48,000 cu. ft. of air per min., which are available with four different systems for sludge removal. Another exhibit was a type C cyclone connected to a Drytube 500 filter for collecting fine dust particles.

The exhibits of the Aerograph Co., Ltd., 47 Holborn Viaduct, London, E.C.1, included water

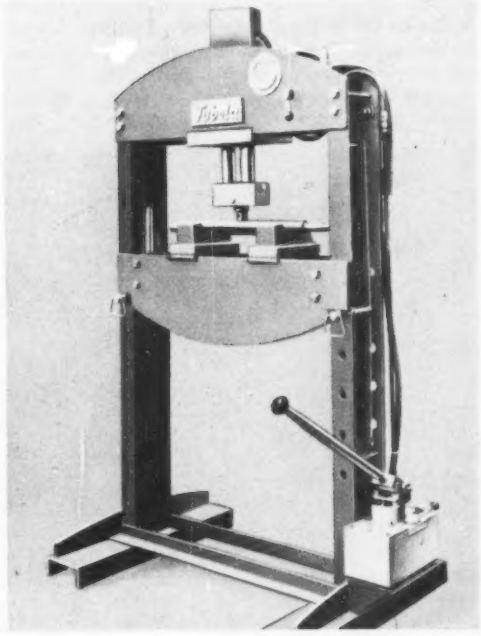


Fig. 5. Tubela 20-ton Hydraulic Press

wash and canopy-type spray booths, a new portable hot spraying unit, equipment for spraying catalyst and additive materials, and an automatic traversing spraying unit. Spray guns for handling most types of paints and finishing materials, and examples from the firm's range of portable and stationary air compressors were also on view.

The Martinet wet-dry suction cleaner, for the removal of dirt and fluids from workshop floors and other parts of factory buildings, was shown by Martindale Electric Co., Ltd., Westmorland Road, London, N.W.9. One of the latest additions to the company's range of products, this equipment comprises a wheel-mounted 4-gal. tank of rust-proof metal which can be used with any standard Martindale portable electric blower and various types of hose and suction tool attachments.

Weighing less than ½ oz., a protective face mask, which was shown, comprises a frame of soft rolled aluminium and a renewable gauze filter pad. A feature of the mask is that the frame can be formed by the fingers to give a snug fit over the nose and mouth. Other protective clothing on view included a new range of p.v.c. coated fabric gloves.

Among the exhibits of Minnesota Mining and Manufacturing Co., Ltd., 3M House, Wigmore Street, London, S.W.1, was noted the recently-introduced Safety-Walk non-slip surfacing material for factory floors, stairways ramps, and gangways, for example. Part of a workshop floor surfaced with this material is shown in Fig. 7.

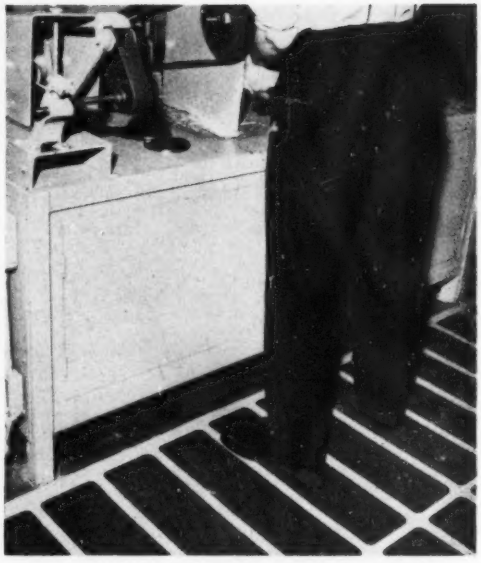


Fig. 7. Part of a Workshop Floor Covered with Safety-Walk Non-Slip Surfacing Material

Stated to be water-proof, weather-proof, and unaffected by vibration, shock, heat, cold, oil, or petrol, the material consists of a surface coating of very hard mineral grains on tough fabric. It is available in two grades, and can be applied to concrete, marble, terrazzo, tiles, wood, and steel and iron plates.

Other items on view included examples from the firm's extensive range of Scotchboy adhesive tapes which find numerous applications in the electrical industry, Scotchrap wrapping tapes for the protection of pipes and cables from chemical and electrolytic action, and Scotchlite reflective sheeting.

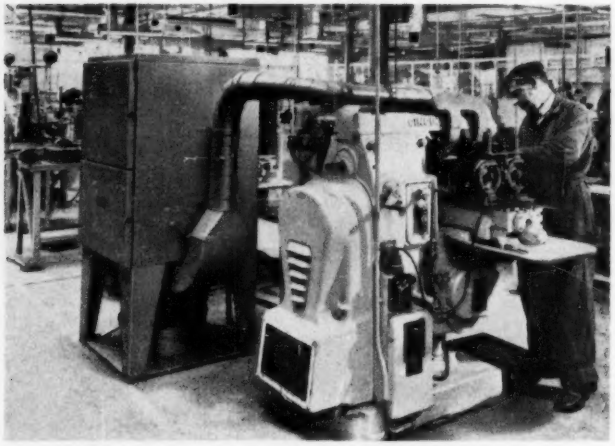


Fig. 6. Dallow Lambert Dustmaster Type D.M101 Dust Collecting Installation for a Milling Machine

ELECTRIC VACUUM CLEANERS—During 1957, the average monthly delivery of electric vacuum cleaners was 103,800 units, and, on average, 21,200 units per month were exported. For the year 1956, the average monthly delivery of vacuum cleaners was 85,000 units, and, on average, 18,300 units were exported. During 1955, the figures were 103,200 and 16,300 units, and for 1954, 101,600 and 24,100 units.

News of the Industry

Yorkshire

JOHN LUND, LTD., Cross Hills, Keighley, are well placed for orders for Precimax plain and universal cylindrical grinding machines and fine boring machines. A large contract has been placed by a Spanish motor-car factory, and other orders are in hand for France and India. We noted a machine for Australia, for grinding refrigerator rotors, and two 10- by 72-in. plain grinders are destined for the U.S.A. In the works we noted small, medium, and large capacity plain and universal grinders in progress, including angle-head type machines.

Many of the fine boring machines in progress are destined for the motor-car industry, and they include single- and double-ended types, with single and multi-spindles. We hope shortly to make further reference to a 4-way fine boring machine built for the aircraft industry, and to a 3-spindle, single-ended machine, which has been supplied to a Scottish firm for operations on 6-cylinder diesel engine blocks. Our attention was drawn to the firm's new design of 20/25-ton rotary-type surface grinding machine, which we hope to describe shortly. A new canteen has recently been built, and as a result additional shop floor space has been made available. Recent additions to plant include a Ward combination turret lathe, an Armstrong vertical honing machine, and a Precimax 12- by 72-in. cylindrical grinding machine.

A new 20-page brochure has been issued describing the Precimax FB1 and FB2 fine boring machines. It contains numerous illustrations and diagrams, and production data are included for many interesting set-ups, with production data.

FAIRBANK BREARLEY, Bingley, are doing a steady trade in their various types of spring-plate machinery, and export orders are in hand for India and New Zealand. We noted in progress spring eye rolling machines, including a double-ended type, spring forging machines, hydraulic and pneumatic coil and laminated spring scragging machines, and buckle presses.

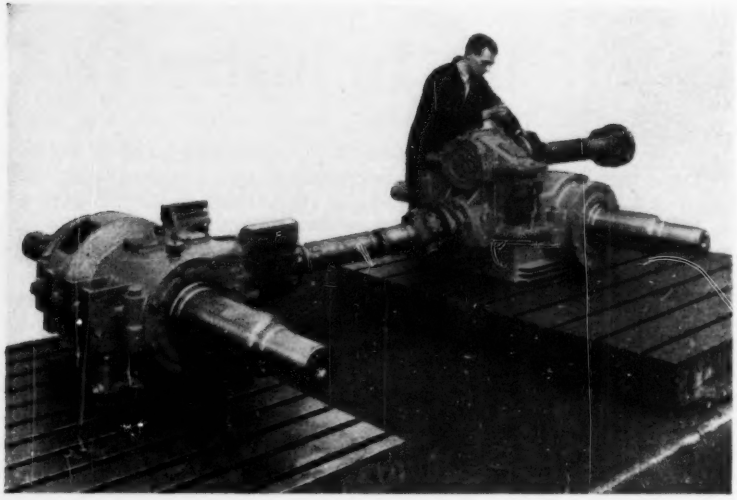
B. SMITH & SON, Bingley, in addition to their wood-working machinery, which includes single and gang mortising machines, hinge and lock recessing machines, and haunching and wedge cutting machines, are producing machine tool components under contract, and are carrying out lathe reconditioning work. There is a steady demand for a variety of tooling equipment.

INDIVIDUAL TOOLS, LTD., Bingley, have recently extended their range of irregular seaming machines to cover diagonals up to 44 in., in 14-gauge steel sheet. These machines are now available for diagonals from 2¾ in. in tinplate up to the size indicated, and continuous bending dies for the double-seaming operations are also being produced. Modifications have recently been made to the firm's taper neck oil drum seaming machines to enable interrupted chime drums to be handled. Other work includes round seaming machines for household cylinders of copper, and a variety of press tools for dust bins, body blanking dies, combination tools for lids and double-seam bottoms, and special grooving tools.

BROOK MOTORS, LTD., Empress Works, Huddersfield, have recently completed two new 16-mm. black and white sound films. The first, entitled "Six Hundred Horses," has a running time of 14 min., and shows the production of large electric motors as seen through the eyes of a visiting customer. The second film, entitled "Not by Magic," covers, in 16 min., a number of varied electric motor applications. The company has recently issued a loose-leaf catalogue of the various films to which fresh sheets may be added when further films become available. Copies of this catalogue can be obtained on application to the Film Division.

DAVID BROWN INDUSTRIES, LTD., Park Works, Lockwood, Huddersfield, have recently received an order valued at nearly £250,000, from the North British Locomotive Co., Ltd., Glasgow, for axle-mounted gearboxes. This order follows the placing of a contract by British Railways for 52 main-line diesel-hydraulic locomotives—the largest single order so far assigned to one company for locomotives. These 52 units, each of 1,000/1,100 b.h.p., will provide for the first major stage of a scheme for replacing steam by diesel traction in British Railways' Western Region.

Fifty-six sets of the David Brown gearboxes have been ordered, each set comprising two primary and two secondary units. Each of the primary units will provide a 2-stage reduction,



David Brown Axle-mounted Gearboxes for Locomotives are Here Being Set Up for Test Running

first through single-helical gears and then through spiral bevel gears, while the secondary units will give a single reduction through spiral bevel gears. Production of the gearboxes will be at the rate of three sets per month, to keep pace with the scheduled monthly delivery of three locomotives. The accompanying illustration shows axle-mounted gearboxes being set up for test running at the Huddersfield works. H. B.

The Midlands

STUART DAVIS, LTD., Much Park Street, Coventry, report a sustained demand for their Red Ring air cylinders and pneumatic equipment, some examples of which are to be shown at the forthcoming Brussels International Exhibition. Arrangements have also been made for this firm's products, together with machine tools for which they hold agencies to be displayed at exhibitions in Tokyo, Japan, and Philadelphia, U.S.A. Orders are being received for 4-stage cold-heading machines, on which a wide range of component forms can be produced from bar stock up to ⅞ in. diameter. We hope shortly to publish details of a flank-angle checking machine which this company has recently introduced.

TORNOS SALES CO., Broadgate House, Coventry, are experiencing a good demand for Tornos automatics which are used extensively for the manufacture of precision components, including watch and instrument parts. We understand that it is now possible to quote slightly shorter delivery periods for these machines. The company has recently arranged to distribute, in this country, the small bench surface grinding machine made by Lip Industrie. In addition, the selling agency for Agathon cemented-carbide tool grinding and lapping machines has recently been acquired.

HOWARD CLAYTON-WRIGHT, LTD., Wellesbourne, Warwickshire, report that the recently-introduced Nylastic bearings are being used with success in a variety of industrial applications. The synthetic-bearing material is fitted, in the form of a liner, to a metal housing. A gap in the wall of the bearing material permits circumferential expansion due to absorption of moisture and changes of temperature. It is claimed that Nylastic bearings operate satisfactorily under adverse conditions, are silent, and may be lubricated effectively with many liquids, including water.

Following extensive tests, these bearings have been found suitable for aircraft, motor vehicle, and marine use, for oscillating and rotary motions under certain specified conditions. Where increased radial resilience is required, these bearings may be inserted in Clayflex flexible bushes.

REDGRAVE DEAN & CO., LTD., Station Road, Coleshill, Warwickshire, report a steady demand for their barrel polishing machines, which are used by manufacturers of spring clips, instrument parts, jewellery, and small machined components. This company can also supply a wide range of barrelling media to meet the requirements of different industries. Facilities are available for processing samples of customers' products in order to determine the most suitable media for polishing particular components. The company is also well equipped for the production of fabricated steel structures—in particular the main frames of machine tools. Oxygen flame cutting machines are extensively employed for producing profiled shapes from steel plate. F. W. H.

European Machine Tool Committee

Members of the European Committee for Co-operation of the Machine Tool Industries were impressed by a recent visit to the site of the new Centre National des Industries et des Techniques. Monsieur E. Pouvreau, who is President of this body and a Vice-President of the European Committee, gave many details of its construction as well as of the vast project for industrializaing the neighbouring zone.

In September this year the Mecanelec national exhibition will be staged on the lower floor of the new building, which provides an area of 35,000 sq. metres. In 1959 the whole of the space, amounting to about 100,000 sq. metres, will be in use for various shows. From September 12 to 21, 1959, the 6th European Machine Tool Exhibition will be held there. The General Commissar will be Monsieur B. Gardair (France), who was appointed to this office at a recent meeting. In addition, Monsieur P. Raskin (Belgium) has been elected President of the Exhibition Committee, and Monsieur E. Deletaille (Belgium) and Herr R. Boehringer (Germany) have been elected, respectively, to the chairs of the committees for Economic Expansion and for Technical Education.

The Committee established the main principles of the regulations which will underlie the organization of the 6th European Machine Tool Exhibition, and made further arrangements for the wide circulation of the publicity brochure urging replacement of obsolescent machine tools, which should be ready during the summer of this year.

New Companies Registered*

J. A. WILLIAMS & SONS, LTD., 30 Birmingham Road, West Bromwich. Registered March 26, 1958. To carry on the business of engineers, casters, etc. Nom. cap.: £10,000 in £1 shares. Directors: John A Williams (chairman) and A. B. Williams.

ALEXANDER SOCKET SCREWS LTD., Gunns Lane, West Bromwich. Registered March 10, 1958. To carry on the business of manufacturers of socket screws, grinding wheels, machines, tools, etc. Nom. cap.: £10,000. Permanent directors: Geo. H. Alexander, J. W. Alexander and Geo. F. Alexander.

FAIRHURST ELECTRONICS LTD., 228/232 Corn Exchange Buildings, Hanging Ditch, Manchester, 4. Registered March 3, 1958. To enter into an agreement with James Fairhurst and to carry on the business of precision engineers, etc. Nom. cap.: £10,000. Directors: J. Redfern, J. Fairhurst, G. N. Ainsworth, R. J. Brunskill and M. K. Fairhurst.

MECHANDLING LTD., 2 Norfolk Street, Strand, London, W.C.2. Registered March 6, 1958. To acquire from Ewen D. Rands all or any of the rights held by him for the manufacture, sale, repair, conversion and alteration of conveyors, belting and other handling equipment, and to carry on the business of mechanical and electrical engineers, founders, etc. Nom. cap.: £20,000. Directors: E. D. Rands and H. Graham-Brown.

* From the lists compiled by Jordan & Sons, Ltd., Company Registration Agents, 116-118 Chancery Lane, London, W.C.2.

Obituary

MR. ARTHUR JOHN HEWITT, O.B.E., director and general manager of the Coventry Gauge & Tool Co., Ltd., died recently in hospital after an illness of several months. Educated at Bablake School, Coventry, he was with Alfred Herbert, Ltd., for a short time, before he joined the late Sir Harry Harley in 1917, at the original premises of the company in Warwick Street, Coventry. He had thus been associated with the business for more than 40 years.

Mr. A. J. Hewitt

In January, 1943 he was made a director, and in the same year he was awarded the O.B.E. for outstanding work in connection with the production of all kinds of war materials.

Correction

In the advertisement for Gaston E. Marbaix, Ltd., Devonshire House, Vicarage Crescent, Battersea, London, S.W.11, which appeared on p. 55 of MACHINERY for April 18, the capacity of the Model No. 10 Barnesdril magnetic automatic coolant separator was given incorrectly. The separator of this size has a capacity of 103 gal. per min. of water soluble oil coolant.

Precision Forging

(*Continued from page* 931)

Apart from such possibilities, forged gears normally have considerably greater tooth strength than cut gears, by reason of the grain formation, and increases of as much as 100 per cent have been reported. This high strength should be of value for various applications, particularly in aircraft. Hitherto, the normal carburizing grades of steel have been principally employed for precision forged gears, but it is understood that the process has also been applied with some success to through-hardening, stainless, and tool steels. It has also been suggested that where gears must be made from high temperature steels or titanium, forging techniques might enable considerable savings to be effected.

As with other comparatively new processes, it is evident that if the potentialities of precision hot forging are to be fully exploited, parts must be designed with a knowledge of the possibilities and limitations of this method.

Industrial Notes

HUBERT H. P. TRIST & CO., LTD., Topdog Works, Brislington, Bristol, 4, are now licensed to manufacture asbestos friction materials to the processes and formulae of the Thermoid Co., Trenton, New Jersey, U.S.A.

MASSEY-FERGUSON is the new name which has been adopted for the United Kingdom companies of the agricultural machinery organization formerly known as Massey-Harris-Ferguson, also for the products of these companies.

THE NUMBER EMPLOYED IN MANUFACTURING INDUSTRY fell by 16,000 in January, from 9,300,000 to 9,284,000. There was a decline of 2,000 in "metal manufacture" and of 2,000 in "engineering, metal goods, and precision instruments," but an increase of 3,000 in "vehicles."

EMERY AIR FREIGHT CORPORATION, 5 Oddfellows Cottages, 71 Bath Road, Hounslow, Middlesex, inform us that all 503 airport cities in the U.S.A. can now be reached in less than 48 hours by their air freight service. Full particulars can be obtained from the above address.

WOLF ELECTRIC TOOLS, LTD., have acquired an additional factory on the Slough Trading Estate. The new premises, which will provide an extra 15,350 sq. ft. of floor space, are to be used for promoting planned technical developments. This company now has five factories.

BARLOW-WHITNEY, LTD., inform us that their Midlands office has been moved to 44 Queen's College Chambers, Paradise Street, Birmingham, 1 (telephone number, Midland 6897). This address is now the headquarters of the Midlands area manager, Mr. H. Melrose, A.M.I.E.E., A.M.C.T.

URWICK, DIEBOLD, LTD., is the title of a new company which is being formed by John Diebold & Associates, Inc., U.S.A., and Urwick, Orr & Partners, Ltd., to provide a consulting service to British business on problems concerned with the installation of electronic computers. The address of this new company is 29 Hertford Street, London, W.1.

A NEW PERMALI GROUP FACTORY was recently opened at Gloucester and on the same occasion the 21st anniversary of the company was celebrated. This factory now houses the combined production of Permali, Ltd., Hordern-Richmond, Ltd., and Jabroc, Ltd., and is said to be the largest plant in Europe for the manufacture of densified wood laminates.

ROTAX, LTD., Willesden Junction, London, N.W.10, have begun publication of the *Rotax Technical Journal*. The first issue, which is well presented, comprises 32 pages, and includes notes on epic flights, also articles under the following headings: high rupturing capacity test equipment for aircraft switchgear; environmental test equipment; and an aircraft electrical systems test laboratory.

METROPOLITAN-VICKERS ELECTRICAL EXPORT CO., LTD., have received an order, valued at nearly £5 million, from the Argentine Power and Water Board, for the supply and construction of seven 132,000-volt sub-stations to be installed in the Buenos Aires City area. The order, it is stated, is the largest for this type of equipment ever placed with the company.

EVERSHED & VIGNOLES, LTD., Acton Lane Works, Chiswick, London, W.4, have re-organised part of their factory to provide for increased production of their Ducter low resistance testing set, for which there is a growing demand. The direct reading instrument provides for the measurement of resistance values from a few ohms down to 1 microhm.

STANHOPE MACHINE TOOLS, LTD., 5-17 Haverstock Hill, Chalk Farm, London, N.W.3, sole distributors for the Ainjest high-speed screwcutting attachment, have appointed W. O. Bullock & Sons, Ltd., Rodbourne Road, Swindon, Wilts., as their sole representatives for this attachment in Cornwall, Monmouthshire, Somersetshire, Herefordshire, Devonshire, Wiltshire, Gloucestershire, and Glamorganshire.

ENGLISH ABRASIVES CORPORATION, LTD., inform us that they have established a central administrative office at their London factory at Marsh Lane, Tottenham, N.17, for their group of companies, from which all activities will be controlled in future. The subsidiary companies are Thos. Goldsworthy & Sons, Ltd., Manchester; Helvetia Abrasives Co., Ltd., Leicester; and London Abrasives, Ltd., Tottenham.

A. LAWRENCE & CO. (MACHINE TOOLS), LTD., Welsh Harp, Edgware Road, London, N.W.2, are now handling keyseating machines made by Carter & Wright, Ltd., Halifax. These machines are built in various sizes for slot widths up to 1½ in. and lengths from 6 to 30 in., and for internal vertical keyseating up to ¾ in. wide by 9 in. long. All these machines are available for inspection at the showrooms at the above address.

INDUSTRIAL BUILDING.—Provisional figures indicate that in the first quarter of 1958 industrial development certificates were granted in respect of 583 building schemes representing a total area of 11.8 million sq. ft. These figures relate to new building and extensions, exceeding 5,000 sq. ft., for manufacturing industry. For the full year 1957, the totals were 2,424 and 64 million sq. ft., and for 1956, 2,470 and 71.8 million sq. ft.

ENGLISH CLOCK SYSTEMS and SMITHS INDUSTRIAL INSTRUMENT DIVISION (both members of the Smiths Group of Companies) have opened combined showrooms and offices at 184 Corporation Street, Birmingham 4 (telephone number, Central 8737). The range of equipment made by these companies covers the field of time control, also timing and measuring operations in industry and commerce.

EUROPEAN INDUSTRIAL CONSULTANTS, LTD., is the title of a consultancy business which is being started by Mr. John A. Grainger and Mr. Henry W. Lawton. The address of the company is Dudley Road East, Oldbury, Birming-

ham. Mr. Grainger has also joined the engineering business of Henry W. Lawton, Ltd., also at Dudley Road East, Oldbury, as a director.

In addition, Lawton Heat Treatment, Ltd., has been registered, and has started trading from the above address.

E. H. JONES (MACHINE TOOLS), LTD., inform us that their new premises have now been completed and occupied, so that their London area address is 48 High Street, Edgware (telephone number, Edgware 4488/9). At these premises there is a large warehouse for used machines, and a well appointed showroom is equipped for working demonstrations. In addition, provision has been made for the introduction of a spares service for C.V.A. automatics and dieing presses.

THE BRITISH VACUUM CLEANER & ENGINEERING CO., LTD., Goblin Works, Leatherhead, Surrey, report that they recently supplied equipment to the De Havilland Engine Co., Ltd., for removing coolant, swarf, and sludge from 37 machines. For this purpose, a 6-h.p. petrol engine driven exhauster is mounted on a truck with a 300-gal. wet intercepter, the latter being provided with a 6-in. valve for emptying. It is stated that, with this equipment, the work is completed by one operator in 2 hours on a Saturday morning.

THE BRITISH COMPRESSED AIR SOCIETY, 32 Victoria Street, London, S.W.1.—In the annual report of the Society it is stated that deliveries by British manufacturers of compressed air equipment in 1957 reached a record total of more than £21 million. The value of exports was also the highest yet recorded, and exceeded the figure for 1956 by £500,000. At the recent annual general meeting, Mr. W. B. Rainbird (Climax Rock Drill & Engineering Works, Ltd.) was appointed President, and Mr. E. A. Martin (Padley & Venables, Ltd.), Vice-President.

INCORPORATED PLANT ENGINEERS, 12 The Parade, Solihull, Warwickshire.—At the 11th annual conference, to be held at the Grand Hotel, Brighton, from May 14 to 16, the theme will be " the exploitation of change " to take account of " the needs of the times, and of the opportunities which now exist for the plant engineer to introduce improved techniques." In view of the large response to a similar invitation last year, the Council is opening the conference to non-members by again inviting a limited number of industrial concerns to nominate staff to attend.

SHORT & MASON, LTD., Aneroid Works, 280 Wood Street, Walthamstow, London, E.17, have signed an agreement with A.-G. Chemisches Institut Dr. A. G. Epprecht, Zurich, whereby they will act as sole agents in Great Britain for the range of Drage instruments. An instrument application department has been set up to advise on the use and installation of the instruments which include torsional viscometers and rheometers, also plant assemblies for automatic control of viscosity. In addition, the new Drage Multitest tensile, compression and bending test machine will be marketed.

NEWALL GROUP SALES, LTD., Peterborough, inform us that arrangements have been made for an exhibition and demonstration of two machines at the works of Keighley Grinders (M.T.), Ltd., Aireworth Road, Keighley, from April 28 to May 7 (from 9 a.m. to 6 p.m. daily).

The machines on view will be a Newall 2436 jig borer equipped for high accuracy shave milling, and a Keighley type KLGG gauge grinder of 3½-in. centre height, with a grinding length of 9 or 18 in., for superfine grinding, to the order of 0.4 micro-inch finish, under normal working conditions.

MARCH STEEL AND IRON PRODUCTION.—Steel production in March averaged 432,300 tons a week, compared with 427,500 tons a week in February and 431,000 tons in March, 1957. Production in the first quarter of 1958 totalled 5,475,000 tons, compared with 5,532,000 tons in the corresponding period of 1957.

Pig-iron production in March averaged 267,000 tons a week, as against 272,700 tons in February and 277,200 tons in March, 1957. For the first quarter, pig-iron production totalled 3,516,000 tons this year, compared with 3,464,000 tons in 1957.

SCIAKY LIVERPOOL EXHIBITION.—A selection of resistance welding machines made by Sciaky Electric Welding Machines, Ltd., Falmouth Road, Slough, Bucks., will be exhibited in conjunction with the Merseyside and North Wales Electricity Board at their Industrial Development Centre, Cleveland Square, Paradise Street, Liverpool, from May 12 to 23. Technical staff will be available to demonstrate the equipment and give advice. On May 15, at 6.30 p.m., an illustrated lecture on resistance welding will be given at the Centre.

At the exhibition, the Speedforge range of projection welders will be introduced, and various electronic controls will also be shown.

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25/4/58

Personal

MR. N. D. G. ROBERTSON who has been managing director of The Non-Ferrous Die Casting Co., Ltd., since its inception has resigned from the board. He will, however, continue to act in the capacity of consultant. His son, MR. N. D. G. ROBERTSON, has been appointed to succeed him as managing director and MR. G. C. PRAILL has been appointed a director of the Company.

MR. ARTHUR LEGGETT, M.B.E., M.I.Mech.E., M.I.Prod.E., chairman and managing director of E. R. & F. Turner, Ltd., Foxhall Works, Ipswich, has retired from active business after 66 years' service with the company. A presentation and dinner were arranged in honour of the occasion at the Great White Horse Hotel, Ipswich, and many of his business friends and colleagues attended.

Mr. Leggett started as an apprentice with his firm in 1892, became a director in 1918, and managing director in 1932. At the request of his fellow directors he will continue as chairman. He is succeeded by his two sons, Mr. P. A. Leggett and Mr. A. H. Leggett, as joint managing directors.

Two new directors have been appointed to the board, namely Mr. C. B. Wyatt, M.I.E.E., and Mr. A. R. Roote. Mr. J. E. Wright continues as director and company secretary.

Machine Tool Share Market

Stock markets, which had been firm in mainly quiet conditions, became fairly active following the Budget proposals, and the past week closed on a cheerful note.

An outstanding feature was the broadening of interest in the commercial and industrial sections. The shares of companies which stood to benefit from the changes in profits tax and purchase tax commanded most attention, and although prices showed some irregularity, changes, on balance, were to higher levels.

In the gilt-edged market, the trend was favourable, British funds and kindred stocks being highest at the finish.

Among machine tool issues, Asquith Machine Tool advanced 3d. to 17s. 9d.; Birmingham Small Arms, 2s. 6d. to 27s. 6d.; British Oxygen, 1s. to 35s. 6d.; Churchill Machine Tool, 9d. to 18s. 6d.; Geo. Cohen, 6d. to 12s.; Alfred Herbert, 2s. 6d. to 65s.; John Shaw & Sons (Wolverhampton), 1½d. to 11s. 10½d.; and Thos. W. Ward, 2s. 6d. to 77s. 6d. On the other hand, Edgar Allen lost 3d. at 28s.; Butler Machine Tool, 3d. at 6s.; Expert Tool, 3d. at 1s. 3d.; John Holroyd, 3d. at 10s. 3d.; Kitchen & Wade, 6d. at 9s. 9d.; and Newall Engineering, 6d. at 4s. 6d.

COMPANY		Denom.	Middle Price
Abwood Machine Tools, Ltd.	Ord.	1/-	9d.
Armstrong, Stevens & Son, Ltd.	Ord.	5/-	6 7½
Allen (Edgar) & Co., Ltd.	Ord.	£1	28/-
" " "	5% Prf.	£1	15/-*
Arnott & Harrison, Ltd.	Ord.	4/-	13/9
Asquith Machine Tool Corp., Ltd.	Ord.	5/-	17/9
" " "	6% Cum. Prf.	£1	17/9
Birmingham Small Arms Co., Ltd.	Ord.	£1	27/6
" " "	5% Cum. "A" Prf.	£1	15/6
" " "	6% Cum. "B" Prf.	£1	17/6
" "	4% 1st. Mort. Deb.	Stk.	85/-
British Oxygen Co , Ltd.	Ord.	£1	35/6
" " "	6½% Cum. Prf.	£1	21/6
Brooke Tool Manufacturing Co., Ltd.	Ord.	5/-	5/-
Broom & Wade, Ltd.	Ord.	5/-	9/4½
" " "	6% Cum. Prf.	£1	17/9
Brown (David) Corporation, Ltd.	5½% Cum. Prf.	£1	14/4½
Buck & Hickman, Ltd.	6% Cum. Prf.	£1	17/6
Butler Machine Tool Co., Ltd.	Ord.	5/-	6/-
" " "	5% Cum. Prf.	£1	13/9
C.V.A. Jigs, Moulds & Tools, Ltd.	5½% Red. Cum. Prf.	£1	13/9
Churchill (Charles) & Co., Ltd.	Ord.	2/-	4/6
" " "	6% Cum. Prf.	£1	25 7½xd
Churchill Machine Tool Co., Ltd.	Ord.	5/-	18 6
" " "	6% Cum. Prf.	£1	18/9
Clarkson (Engrs.), Ltd.	Ord.	5/-	11/-
Cohen (George), Son & Co., Ltd.	Ord.	5/-	12/-
" " "	4½% Cum. Prf.	£1	14/6
Coventry Gauge & Tool Co., Ltd.	Ord.	10/-	13/3
" " "	5% Cum. Red. Prf.	£1	16/3
Coventry Machine Tool Works, Ltd.	Ord.	4/-	9/-
Craven Bros. (Manchester), Ltd.	Ord.	5/-	6/-
Elliott (B.) & Co., Ltd.	Ord.	1/-	3/-
" " "	4½% Red. Cum. Prf.	£1	13/9
Export Tool & Case Hardening Co., Ltd.	Ord.	2/-	1/3
Firth Brown Tools, Ltd.	4% Cum. Prf.	£1	12/6
Greenwood & Batley, Ltd.	Ord.	£1	46/10½
Harper (John) & Co., Ltd.	Ord.	5/-	14/-
" " "	4½% Red. Cum. Prf.	£1	13/1½
Herbert (Alfred), Ltd.	Ord.	£1	65/-
Holroyd (John) & Co., Ltd.	"A" Ord.	5/-	10/3
" " "	"B" Ord.	5/-	9/9
Jones (A. A.) & Shipman, Ltd.	Ord.	5/-	20/9
" " "	7% Cum. Prf.	5/-	5/-
Kayser, Ellison & Co., Ltd.	Ord.	£1	45/-
" " "	6% Cum. Prf.	£1	18/3
Kendall & Gent, Ltd.	Ord.	5/-	7/9
Kerry's (Gt. Britain), Ltd.	Ord.	5/-	6/6
Kitchen & Wade, Ltd.	Ord.	4/-	9/9
Martin Bros. (Machinery), Ltd.	Ord.	2/-	2/4½
Massey, B. & S., Ltd.	Ord.	5/-	7/3
Modern Engineering Machine Tools, Ltd.	Ord.	5/-	10/-
Newall Engineering Co., Ltd.	Ord.	2/-	4/6
Newman Industries, Ltd.	Ord.	2/-	2/6
" "	6% Prf. Ord.	5/-	5/6
Noble & Lund, Ltd.	Ord.	2/-	4/9
Osborn (Samuel) & Co., Ltd.	Ord.	5/-	16/-xd
" " "	5½% Cum. Prf.	£1	24/6
Pratt (F.) & Co., Ltd.	Ord.	5/-	20/6
Scottish Machine Tool Corporation, Ltd.	Ord.	4/-	5/3
Shardlow (Ambrose) & Co., Ltd.	Ord.	£1	32/6
Shaw (John) & Sons, Wolverhampton, Ltd.	Ord.	5/-	11/10½
Sheffield Twist Drill & Steel Co., Ltd.	Ord.	4/-	35/-
" " " "	5% Cum. Prf.	£1	15/-
Stedall & Co., Ltd.	Ord.	5/-	4/6
Tap & Die Corporation, Ltd.	Ord.	5/-	7/6
" " "	4½% Deb. 1961-1977	Stk.	82/-
Wadkin, Ltd.	Ord.	10/-	18/9
Ward (Thos. W.), Ltd.	Ord.	£1	77/6
" "	5% Cum. 1st. Prf.	£1	15/6
" "	5% Cum. 2nd Prf.	£1	24/9
Willson Lathes, Ltd.	Ord.	1/-	2/4½

The Middle Prices given in the list are in several cases nominal prices only and not actual dealing prices. Every effort is made to ensure accuracy, but no liability can be accepted for any error. * Sheffield price. † Birmingham price.